Instruments

THE MAGAZINE OF

Measurement and Control

Vol. 15
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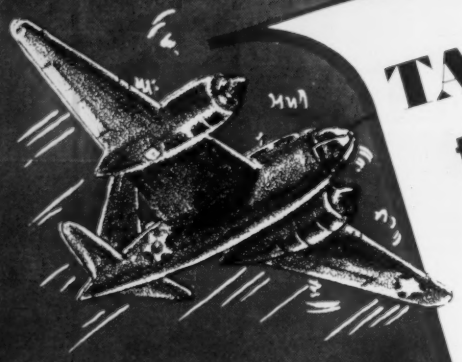
No. 2

TAG

TAG Instruments Control Conditions that Affect War Industry Production and Guard Front Line Performance

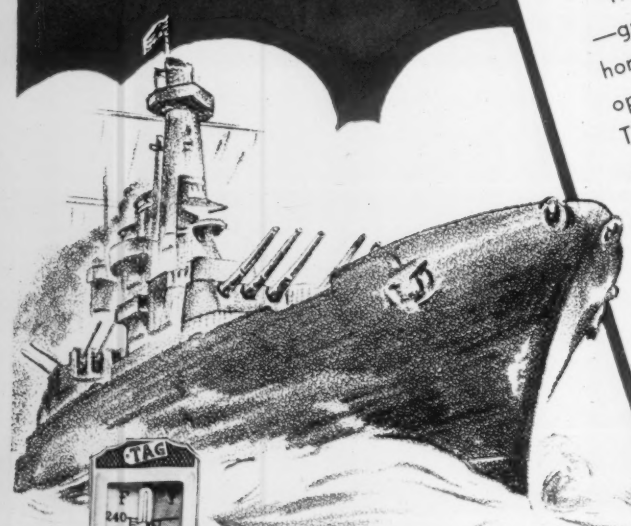


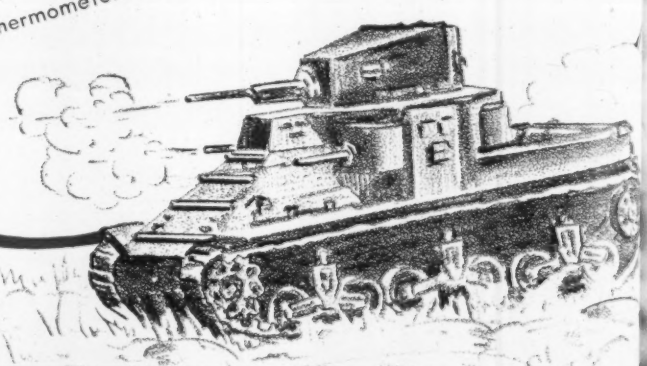
On scores of production lines, the implements of America's rising military might roll out in ever-increasing tempo . . . On every fighting front, the certainty of standardized quality keeps 'em rolling, sailing and flying!

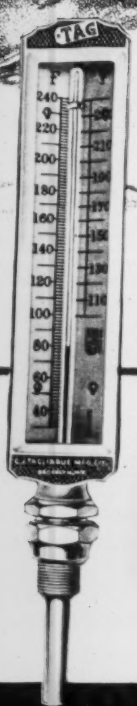
TAG Instruments are recording and controlling manufacturing conditions —guarding against waste and stepping up production on the industrial home front. In the field—tanks, ships, 'planes and motorized equipment operate more effectively because of high standard fuels and lubricants. TAG Oil Testing Instruments in hundreds of laboratories aid in determining and holding these vital standards.

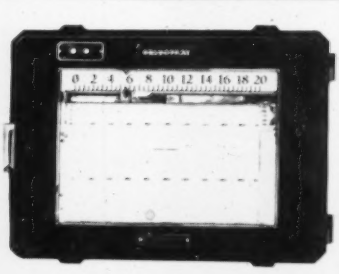
Tie in your war production efforts with TAG . . . save time . . . nip rejects and, above all, step up the pace of production. If you are confronted with a production problem, bring it to us. We have some of the answers and are eager to serve you.

A few of the TAG Instruments now in service in America's War Production efforts are illustrated below, as well as those in action on the fighting fronts. Write for complete information on TAG Indicating, Recording and Controlling Instruments for the plant, and TAG Oil Testing Instruments, Chemical Thermometers and Hydrometers for the laboratory.









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TAGLIABUE BROOKLYN N.Y. U.S.A.

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

. . . But Instrumentation Is a Science

COURSES on various subjects in the vast domain of Measurement and Control are multiplying in all industrial centers. Many of the new technical books devote an increasing proportion of their chapters to industrial instrument subjects. There are more articles on such subjects in the current issues of the technical journals than there were in all the issues of these same technical journals that came off the presses in 1925 or even in 1930.

This suddenly intensified interest in instrument education and training is all for the good of our nation and of our American way of life. It foreshadows faster and faster production, with fewer and fewer man-hours to make each gun or other unit of production. It foreshadows a high American standard of living after the defeat of Hitler and Hirohito when American industry will again face a big job.

This awakening is gratifying to those of us who predicted it ten years ago (a hundred of us at the most). It is gratifying to ten or fifteen of us who preached it and worked for it ten years ago. It is gratifying to me because eighteen years ago, when I alone undertook to bring it about, my efforts were opposed or ridiculed by all but one of the educators, engineers, manufacturers and publishers whom I approached. (Even the kinder ones balked at the word "instrumentation.")

Variables OR "Measurables" OR, IF POSSIBLE Controllables	Methods Choices	Measuring Properties of the Primary Measuring Element or System		Automatic Control addenda	
Simple Magnitudes	Continuous OR Discontinuous		Characteristics of Recording, Transmitting, Registering, etc. Elements	Time elements — characteristics of Final Element or System	The Mode of Control
Simple Quantities	Null OR Deflection				
Properties: Mechanical, Chemical, Electrical, Optical, etc.	Direct OR Indirect				
Conditions: Temperature, Humidity, Pressure (& Vacuum), Level, Fluid Quantity, Fluid Flow Rate, Duration (& Program), Speed, Chem. Prop. of Medium, Elec. Conditions, Light, x-rays, U-v., &c.	Positive OR Inferential	Static: Precision, Scale law, Readability, etc. Kinetic: Sensitivity, Lag, Damping, Drift, Coefficients, etc. (Where is that word "accuracy"?)			
Composition	"Rapid" OR "Slow"				
	"Cheap" OR "Expensive"				
	"Readily available" OR NOT				

A science, according to the Standard Dictionary, is "knowledge . . . methodically formulated and arranged in a rational system." Instrumentation as *things* may mean whatever any user of these things says it means; but Instrumentation as a *science* is the body of knowledge formulated and methodically arranged by The Instrumentation Manual Project. Here is one of the abridged outlines of one formulation-and-arrangement. (Promulgation authorized by The Instrumentation Manual Project but all rights reserved.)

Although the picture is good on the whole, it is far from being excellent when scrutinized closely. In the first place it is sporadic, spotty and jerky. Professor Müller (one of the far-seeing pioneers) pointed out in last month's issue of *Instruments* that "even in a single field, it is remarkable to note how many capable investigators are not fully acquainted with the measuring and instrumental resources of their own subject." He was referring to the field of Instrumental Methods of Chemical Analysis which he had ably reviewed for *Industrial & Engineering Chemistry* last autumn—an *eighty-eight page* review of that single field!

In the second place it is largely a rush to climb on the bandwagon. Some of those who sit smugly on top and smile into camera lenses are the very ones who just got there by elbowing and jostling—the very ones who yesterday were pelting with rotten eggs the handful of pioneer builders of the bandwagon. Well, that's the way it goes in a world of non-angelic human beings. The only thing we pioneers can do is to accept as members of our once-exclusive club those who have crashed the gate. Since they have enrolled as active workers, teachers and writers, in the good cause, they now deserve our encouragement and our ungrudging assistance. I disagree with my fellow-pioneers who explode with anger because, as they say, "ignoramuses are being put in charge of ESMDT instrument courses and other ignoramuses are writing and publishing a lot of tripe." These good friends of mine take the viewpoint that improvised courses and hastily-prepared texts are worse than nothing. My viewpoint is that in this emergency *anything is better than nothing*. One of our missions as pioneers, however, is to hold fast to the custodianship of Instrumentation as a science, to hold up the torch of sound scholarship as an ideal, to maintain and strengthen the foundation on which all newcomers may build, to continue sowing seeds unselfishly so that others may reap. Again I assert that all points of view can be reconciled if all workers from green apprentices to scholarly professors recognize the distinction between instrumentation and Instrumentation—between the array of gleaming dials proudly shown to visitors and the mental concepts which made possible this glorious phase of modern American technology—between the things and the science.

I believe that most newcomers recognize this distinction. I believe that most of those who teach classes, write articles or compile texts are honestly and sincerely taking hold of the *vocational* part of the enormous job, without trying to pose as men of science. I salute them! Moreover, to aid those among them who burn with the holy fire of love of science, there is published for the first time one of the basic formulæ which I developed between 1924 and 1927, when I had to prove that the formulation of a new science, to be called "Instrumentation," was not a wild dream but a useful project. This formula needs a key. The key (one word to the wise) is *Methodology*.

—MFB

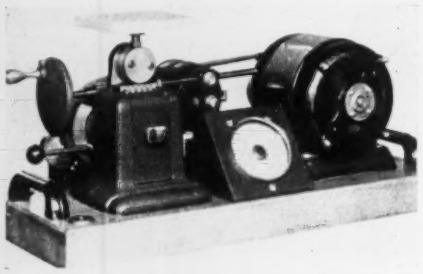
THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control.

When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Vibration Generator

New "Vibratron" is a vibration-producing machine for fatigue testing of aircraft and industrial products. It produces vibrations from 0 to 26 times gravity, has a frequency range from 600 to 3000 cycles per minute adjustable while machine is in operation. Calibrated speedometer has 2% accuracy. Amplitude is variable from 0 to 0.250" total



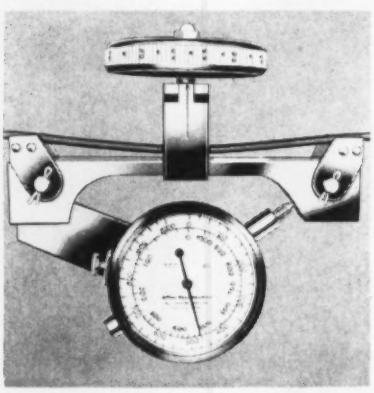
peak to trough, continuously variable by means of a dial resettable to 1%. Cast aluminum vibrating test table is 6" square, has a multitude of holes to facilitate quick change of products under test, carries up to 10 lbs. at maximum vibration. Machine is approx. 3 feet long and weighs 65 lbs. with a 2" hardwood base equipped with handles and sunken steel mounting inserts in its four corners for anchoring when necessary. Standard models operate from 105-120 volts, 60 cycles.—*Televiso Products, Inc., 2400 N. Sheffield Blvd., Chicago, Ill.*

Recording Viscosimeter and Specific Gravity Meter

Continuous measurement of the viscosity and specific gravity of all types of liquids is said to be made possible with a new recording instrument (name not given in announcement) which was originally designed for measurement of fluids used in drilling oil wells but has been successfully adapted for use in other industries. A continuous record of viscosity and specific gravity is recorded on a 12" 24-hour round chart. Viscosity is recorded in centipoises of absolute viscosity and the gravity in lbs./ft.^{3}, lbs./gal. or specific gravity. Viscosity measurement is accomplished by a smooth cylindrical solid metallic rotor on the base of the rotor assembly that is submerged in the fluid to a minimum of 4". This is kept revolving at a constant speed of aprox. 250 r.p.m. by a small synchronous motor. Turning inside a cage containing six stationary blades, it shears the liquid between its surface and the vanes. Torque (proportional to viscosity) is transmitted to the recording mechanism. Rotor is suspended on a weighing mechanism so that buoyant force of liquid (proportional to specific gravity) is also transmitted to instrument in terms of specific gravity. Instrument operates on 110-volt a.c. It can be calibrated and checked for accuracy simply by immersing in water of known viscosity and specific gravity. Height, 5 ft; width, 6"; overall depth 6"; diameter recorder cabinet, 14"; weight (with bracket) 60 lbs.—*Petroleum Instrument Corp., 738 East 3rd Street, Los Angeles, Calif.*

Combination Dynamometer

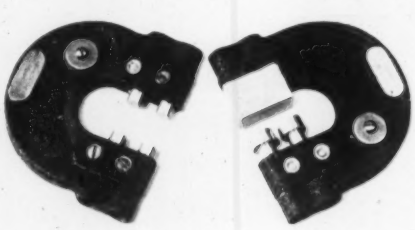
New 1000-lb. "Model STB" (illustrated), and "STA" for higher tensions, provide for the first time, it is said, a combination shunt and traction dynamometer. Instrument slips over established overhead wires,



messenger and guy stands, etc., with a flick of the wrist and shows tension in pounds in less than 60 seconds. For traction reading, top bridge is removed and interchangeable shackles inserted. Inner row of red figures gives shunt readings; outer row of black figures gives traction readings.—*W. C. Dillon & Co., Inc., 5410 W. Harrison St., Chicago, Ill.*

Adjustable Limit Snap Gages

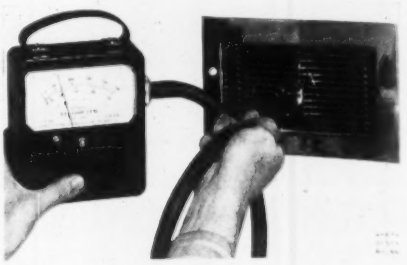
Manufactured in the United States in accordance with American Gage design standards, "Atlantic" Adjustable Limit Snap Gages are built with frames made of Mee-



hanite Castings instead of ordinary gray iron. This alloy was selected by reason of its high tensile strength and because it retains its original form without warping or shrinkage. Atlantic gages are manufactured in two standard types, namely, "Model A" with four gaging buttons and "Model C" with solid block and two gaging anvils. They are now made in thirty different sizes.—*The George Scherr Co., 128 Lafayette St., New York City.*

Grille Jet for Air Velocity Indicator

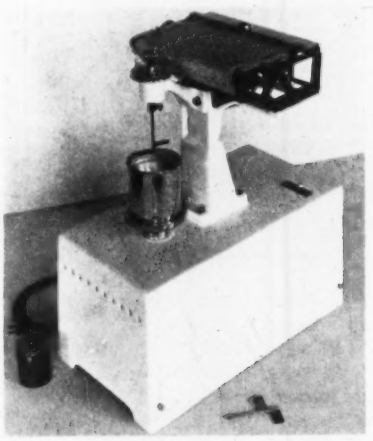
New "Intake or Exhaust Grille Jet," developed for use with maker's "Velometer," has two calibrated air intake openings. One calibrated opening is at end of main member which forms a compensating tube and extends from grille face outward from or beyond critical suction zone, i.e. the zone



where air pressure changes most rapidly from static to velocity. At right angle to this main member is a branch tube, also calibrated, to which is attached the flexible tube connecting jet to Velometer. The air actuating the Velometer movement is inspirated through this branch tube by the suction exerted upon the main member or compensating tube. This intake jet is offered in two sizes—low velocity of $\frac{5}{8}$" OD tubing for full scale ranges of 0 to 1000 f.p.m. and high velocity of $\frac{3}{8}$" OD tubing for scale ranges of 0 to 2500 f.p.m. and higher.—*Illinois Testing Laboratories, Inc., 420 N. LaSalle St., Chicago, Ill.*

Recording Viscosimeter

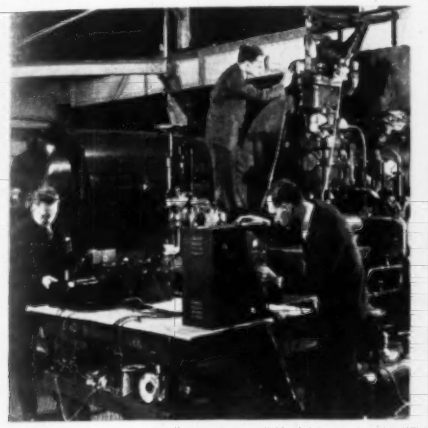
New recording viscosimeter is suitable for all materials of a viscous or light plastic nature, whose properties have to be tested with the additions of thinners or plasticizers, or whose thixotropic effect is important; and generally speaking, wherever it is de-



sirable to obtain a record, in chart form, of the viscosity of a material. Its principle is to turn the material, at a constant speed, and to record on a strip chart the resistance offered by the material against a paddle which is coupled with a calibrated resistance spring. Instrument is highly flexible; it has six different but constant speeds from 30 to 300 r.p.m. and can be supplied with several calibrated resistance springs of different resistance—light, medium and heavy; and a variety of paddle adaptations can be used. Two models: one without and one with temperature control.—*Brabender Corp., Rochelle Park, N. J.*

Turbine Governor Performance Analyzing System

A new system whereby the operation of the component parts of turbine governors can be analyzed comprises several new instruments whose information is relayed electrically to an oscillograph for simultaneous record. One instrument is a valve travel recorder whereby valve movement is



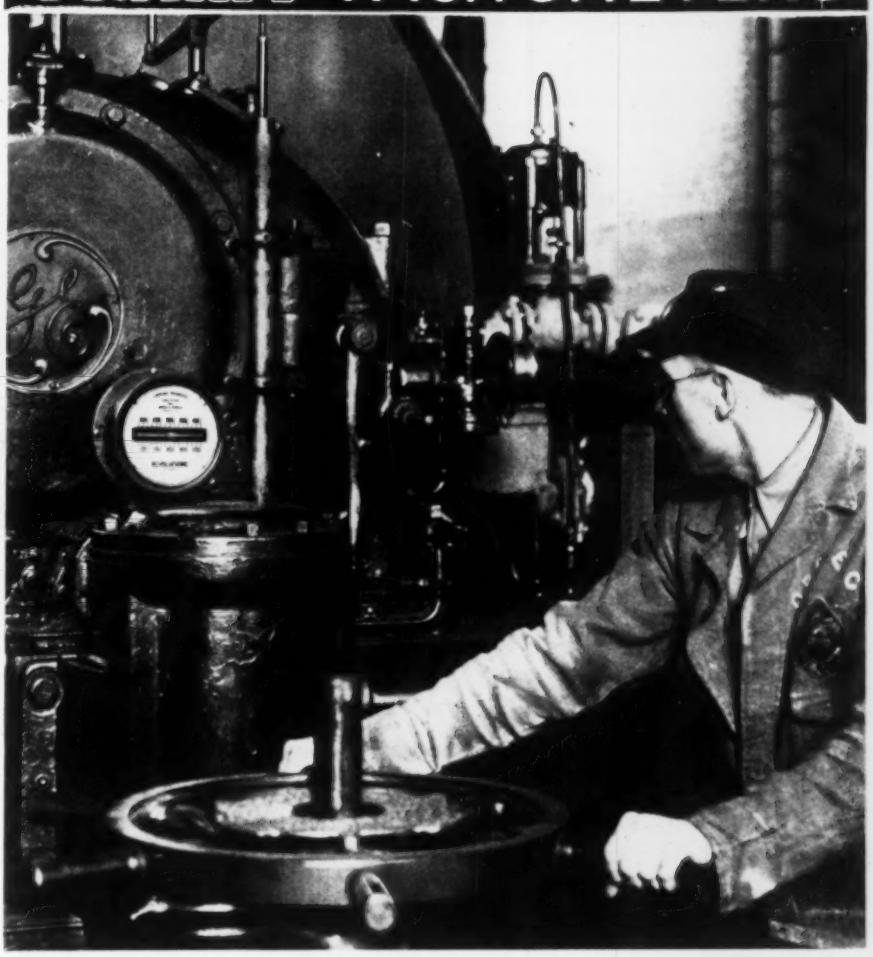
translated into a proportional electrical voltage by a magnetic strain gage. One difficulty that was overcome was the extremely wide range required: it must record accurately as little as 0.05" of travel, or a sudden full travel of 8". Other instruments simultaneously record the several oil pressures involved in the complete control system. A bellows on another strain gage converts pressure changes into proportional voltage changes, is fast enough to record variations in pressure lasting a sixtieth of a second.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Photoelectric Smoke Alarm

New "Type A25C" photoelectric smoke alarm indicates degree of density of smoke passing through stack, signals conditions of efficient combustion and excess smoke on

green and red signal lights. Equipment includes photoelectric "control," light source, and indicator. Photoelectric "control" and light source are mounted on opposite sides of the flue or stack. Design of lens system mounting is said to minimize possibility of soot and dust gathering on lenses. Photoelectric "control" is wired to maker's Densometer "D4" which may be located at any point in the plant.—*Photoswitch Inc., 21 Chestnut St., Cambridge, Mass.*

"FRAHM" TACHOMETERS



A Tachometer that requires no maintenance

The "Frahm" Vibrating-Reed Tachometer does not even have to be oiled because it contains no gears, bearings, rotating or any other wearing parts,—nothing to maintain or even to wear out. There is no electrical system—merely a set of accurately tuned steel reeds which vibrate by resonance according to the speed at which the machine is running. Simply mount the Tachometer in almost any convenient location; the slight vibration in the machine when running does the rest.

For more than 30 years we have supplied these unique speed indicating devices for use on turbines, generators, motors, centrifugal pumps and blowers. Ranges are available from as low as 900 up to 15,000 r.p.m.

More recently our hand type of "Frahm" Tachometer is being used for general speed-measuring work, and also for measuring rates of vibration, such as in pneumatic hammers and drills and in airplanes.

Write for illustrated descriptive Bulletin 1590-I

CENTRIFUGAL TACHOMETERS

We now offer a Heavy Duty Hand Tachometer of the centrifugal, pointer-indicating type. Simple, rugged and reliable. *Ask for Bulletin 1710-I.*

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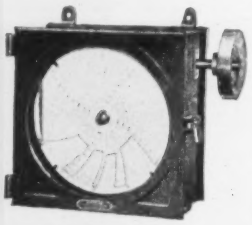
Amthor



Operation Speed Recorder

8" Chart
12 or 24 hr.

Built for severe service. Users report 10, 12 or more years of trouble-free life. Powerful centrifugal speed-measuring element stays calibrated. Non-spill reservoir pen. Special chart paper. Rugged clock movement. Ideal for analysis of new War Effort jobs.

Immediate and intelligent attention will be given to your inquiries on all industrial speed measurement problems. Drop us a line today.

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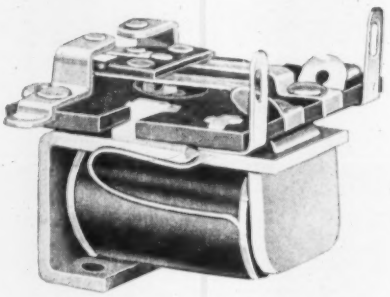
49a Van Sinderen Ave. Brooklyn, N. Y.

Midget Relay

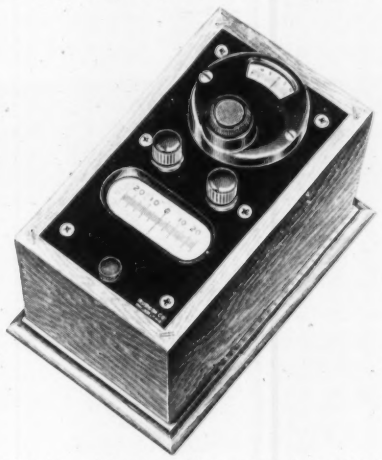
Designed to provide maximum control in minimum space, new "Series 195 D-c. Midget Relay" is particularly suited to aircraft and radio work. Maximum contact capacity is approx. 150 watts at 110 volt, 60 cycle, non-inductive a.c. Manufacturer reports that in aircraft applications the contacts on the new midget are making and



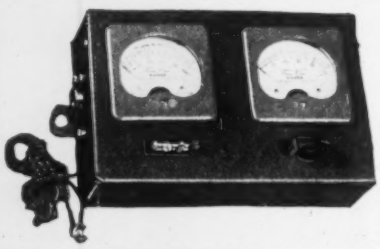
breaking 3 amps non-inductive at 28 volts d.c. Maximum contact combination available is d-p. d-t. With a 2-watt coil and s-p. d-t. contacts in the de-energized position, normally-closed contacts withstand vibrations of six times gravity; normally open contacts withstanding 10 *G*. In the energized position, contacts withstand 10 *G*. Relay coil is available for any voltage up to 75 volts d.c.; maximum resistance 3000 ohms; average power requirements of the coil being 2.5 watts. Coil and contact terminals are solder lug type, tinned for easy soldering. Contact blades are tinned phosphor bronze with contact points of fine silver. Field piece and armature are annealed magnetic iron. Coil is varnish impregnated and baked. Weight with s-p. d-t. contacts is 0.85 oz.—*Guardian Electric Mfg. Co., 1621 West Walnut Street, Chicago, Ill.*

"Pointerlite Galvanometers

In field work, lack of an adequate pow supply for operation of galvanometer la may prove a deterrent to the use of make regular "Spotlight" instruments. Also, p bility may make inadvisable temporary co nection of equipment to commercial supp In recognition of need for highly sensiti instruments for such work, maker has d veloped "Pointerlite" galvanometers. Sen tivities never before attained in galvanom ters designed primarily for portable u are attained, it is said. New galvanometer is a taut-suspension reflecting instrument



equipped with a self-contained multiple-reflection lamp-and-scale optical system and a dry cell of the standard flashlight type for operation of the galvanometer lamp. Indication is by means of a circular spot of light divided by a fine, sharply focused diametral line whose position can be read with ease to within 0.2 mm. division. A zero center scale of 50 mm. divisions is provided. Preliminary zero adjustment is made with an adjustor head; final adjustment by movement of the galvanometer scale. A push button key is provided for controlling the lamp circuit. A pointer index is attached to the galvanometer coil for use when maximum sensitivity of instrument is not required. The associated scale is 30 mm. in length and is marked 15-0-15. All galvanometer systems—comprising magnet, coil, suspensions and supports, pointer index and associated scale, and focusing mirror, all mounted in a cylindrical metal case provided with a molded Bakelite head with zero adjustor—are interchangeable. A variety of characteristics is therefore obtainable without the necessity of procuring several complete galvanometers. "Pointerlite" galvanometers in a slightly modified design are adapted for use as intergral components of portable measuring instruments.—*Rubicon Co., Ridge Ave. & 35th St., Philadelphia, Pa.*



TRU-VAC VACUUM GAUGES
(PIRANI TYPE)

Shown at left is meter box of our model No. 6 gauge.

This gauge successfully used by many of America's foremost manufacturers.

Send for circular on our new low priced D.C. operated gauge.

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Spot Weld Timer

A typical resistance-welding cycle may last from 0.1 sec. to 3 or 4 sec. depending on kind and thickness of metal; total time is further divided into various intervals in which welding machine goes through its operating sequence, and includes a "weld"

period (3 to 30 cycles) when full welding current flows. Sometimes the material is welded not in one, but in several heating and cooling steps intermittently. A controller for this surface has an "overall weld" timing sequence, subdivided in several "heat" and "cool" steps, each ranging from 3 to 30 cycles. This timing is now done by a new controller using plug-in telephone type relays for compactness, and Thyratron tubes to actuate them. The operator, in order to establish the automatic timing sequence for the job at hand, simply places the plugs in the proper holes in the panel of the controller. The controls are mounted on hinged dead-front panels, which, for maintenance, can be swung open by removing a single bolt.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

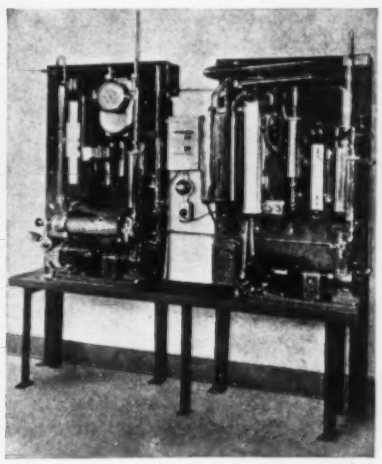
Pyrheliometer

In the new G-E pyrheliometer, the radiation receiver proper is a thermocouple comprising two flat rectangular pieces of a nickel-chromium alloy and a copper-nickel alloy, each 50 millionths of an inch thick, 3/16" long, and 5/64" wide joined end to end. The outer ends of this strip are weld-

ed to vertical lead posts that lead to a stem which is wired for hookup to a millivoltmeter. The end of the stem to which the posts are attached then is sealed into an evacuated glass bulb which in its latest form is a sphere about 2" in diameter. The pyrheliometer is mounted vertically in a fixed position with the thermocouple ribbon parallel to the earth, so that the solar rays will strike this receiver at the same angle as they would hit the earth.—*General Electric Co., Schenectady, N. Y.*

CO Recorder

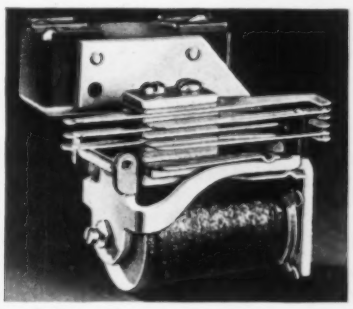
New M.S.A. Continuous Carbon Monoxide Recorder is designed to provide extremely precise measurement and recording of extremely low concentrations of carbon monoxide in air. A refinement of the original M.S.A. Carbon Monoxide Recorder, new instrument finds applications in continuous testing of atmospheres and gases for CO, including use in vehicular tunnels and garages; testing of gas-burning appliances for



determination of CO in combustion-products; testing of various gases for possible CO contamination; and for control practices in manufacturing processes where CO is involved. Range and sensitivity can be varied to suit conditions and results desired. Where sensitivity is of prime importance, calibration covers a range of 0 to 500 ppm. Where a wider range is desired, instrument can be calibrated to cover a range of 0 to 2000 or more ppm.—*Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.*

"Snap-Action" Relay

New "Type 17," an exceptionally small (2¼" × 2¼" × 2½") and light-weight relay for d-c. control of a-c. circuits, provides snap-action contacts (single-pole, arranged to open, close, or switch circuits when the relay operates). Snap-action contacts are of large capacity — will "make" 1150 watts, "break" 690 watts, at 115 volts, ac. Relay



is said to be especially adapted for applications involving extreme humidity or vibration. Coils are impregnated with insulating varnish, and are unaffected by 95% humidity. Impregnation also prevents movement of windings under vibration; all screws are locked into a rigid assembly; adequate mounting holes permit secure fastening. Either one or two snap-action contacts may be supplied. Or, relay can be supplied with one snap-action contact, and one contact spring assembly (up to ten springs). Contact springs are offered with a wide choice of contacts.—*Automatic Electric Co., 1033 W. Van Buren St., Chicago, Ill.*

BAILEY METER CONTROL SYSTEM

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Effective Control

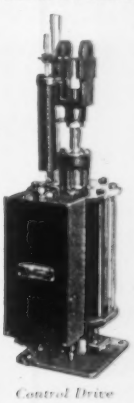
Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.



Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

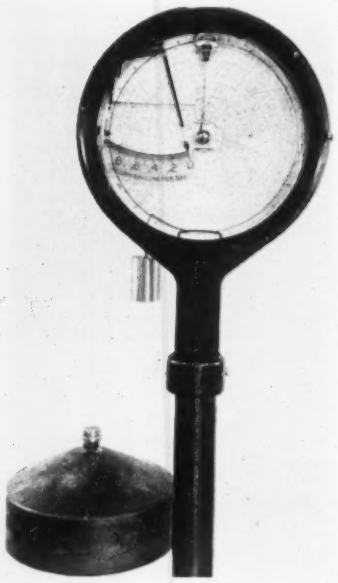
Microphotometer

New "Knorr-Albers Recording Microphotometer" provides a rapid and convenient method for analyzing spectrographic plates or films in research and industrial laboratories. Because plates or films are mechanically scanned by a motor-driven scanning unit, and relative positions and densities of

spectrum lines are automatically recorded by maker's "Speedomax Recorder," new recording microphotometer eliminates eyestrain and "human equation" of visual methods and does away with delays and limitations of photographic processes. Quick determinations of elements "present in small percentages" are made possible by pen-and-ink records of standard and test spectrograms drawn at high speed on one chart. Designed to accommodate plates or films as large as 4" high by 10" wide, scanning unit includes on a heavy cast base, an optical system, a plate stage, a drive mechanism for the plate stage, an a-c. operated amplifier and all necessary controls grouped conveniently. In indicating and recording relative positions and densities of spectrum lines, response of Speedomax recorder to density changes is immediate and rapid: in less than 1.5 seconds the pen moves from one position and comes to rest at its new position (even across entire width of the 9" chart). Pen position can be read at a glance on an indicating scale as the record is being drawn. No unusual skills are required: anyone familiar in a general way with instruments can quickly learn to use new microphotometer.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.*

Float-operated Instruments

A complete line of new float-and-cable operated instruments for flow and liquid level measurement, telemetering and control, with both air and electric operation, is announced. Illustrated is *Flow Meter* which has a new simplified cam mechanism designed for use with the integrator and recording units which are standard in other Foxboro instruments. Standard models are



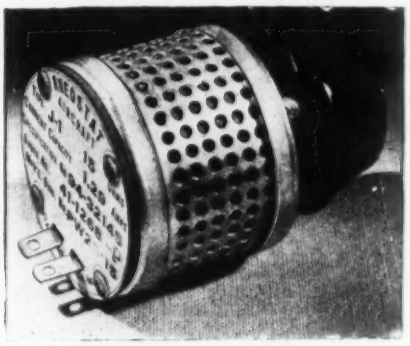
available for V-notch, rectangular, or Sutro weirs and Parshall flumes, with uniformly graduated charts, and with indicating scales reading directly in flow units, and with direct-reading integrator with cyclometer type counter. Complete overrange protection is built in on the cable drum and instrument cam. There is a large external micrometer for easy and precise zeroing in the field. Cases are cast-aluminum, weatherproof and gasketed, and designed for floor pedestal, wall, or flush panel-mounting. All metal parts of the instrument are brass, stainless steel, or nickel-silver, for high-corrosion resistance.

Liquid Level measuring instruments have a different type of float and cable mechanism, using a large double drum. Movement of cable drum is transmitted to pen mechanism through a precision gear train equipped with anti-backlash gears. Standard ranges are from 0-5 to 0-30 feet.

Multi-pen Recorders, including one float-and-cable operated measuring system with other measuring systems for temperature, pressure, liquid level, or flow, are all available through the combination of standard Foxboro instrument units. For example, a record of wet well level is combined with records showing the operation of several pumps. Float-and-cable operated instruments for either flow or liquid level measurement can be combined with any of the standard Foxboro air-operated control mechanisms; or for pumping control, float-and-cable operated instruments are also available with Rotax electric-operated systems.—*The Foxboro Co., Foxboro, Mass.*

25-watt Armored Rheostat

Constructed to withstand exceptionally hard usage, particularly where the unit is exposed, new 25-watt armored type power rheostat is standard equipment in certain types of fighting aircraft. Photo shows per-



forated metal housing and flat lug terminals brought out at rear of casing. Front face has locking pin which engages a hole in panel or mounting surface to prevent turning unit when knob is turned. The ⅜" bushing and nut provide one-hole mounting. New unit employs insulated metal core to support the winding which is imbedded in an inorganic cement. Even at one-third total resistance, the unit dissipates a full 25 watts. Units are available in standard resistance values of 1 to 5000 ohms, other values on special order.—*Clarostat Mfg. Co., Inc., 285-7 N. 6th St., Brooklyn, N. Y.*

A New STAR to Follow in 1942

ECONOMY!

A paramount issue of the Day

Palmer Thermometers, made with extreme care, by skilled American workmen, mean extra life to these instruments, and fewer repairs.

Careful annealing, which is a feature of every Palmer Thermometer, gives you a round dollar value, which should be considered before you sign your next order, for any thermometers.

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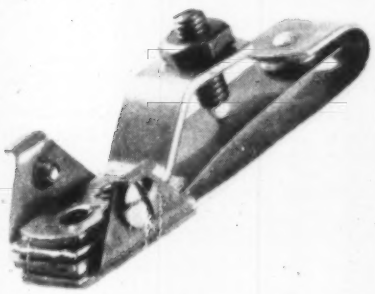
Surface Thermostat

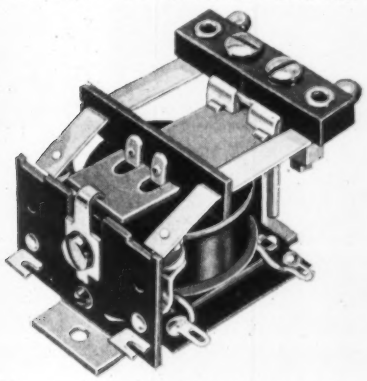
New Underwriter's approved adjustable thermostat, "Type ASK-BB," comprises a ½" bimetal element mica insulated from a ½" spring. Large silver contacts and two insulated mounting holes are also provided. With a maximum operating temperature of



300°, 450° or 700° F., unit handles 1500 watts at 150 or 230 volts a.c. Can be supplied either normally open or normally closed type. Temperature setting by simple adjusting screw. Overall dimensions 2⅜" × ⅝". Especially adapted for use on electrically heated cabinets, flat irons, rubber vulcanizing equipment, radio transmitters, automatic labeling machines, electric airplane heaters, temperature alarms, etc.—*George Ulanet Co., 88 E. Kinney St., Newark, N. J.*

Vibration-resistant Relay

New "Series 165 Vibration Resistant Relay" is designed for applications such as aircraft, generator mountings, etc. *Quantitative data on performance:* Tests by the laboratory of an airline disclosed that Series 165 with two normally-open contacts would withstand 16.2 times gravity without making contact when the coil was de-energized, or breaking contact with the coil energized. Manufacturer claims that 16.2 *G* is not maximum vibration resistance of relay but represents maximum obtainable on



testing machine. Vibration life tests by another user on a production model (since improved) required 230 hours of continuous vibration at 110 cycles per second with relay tested in two positions 90° apart, before it became inoperable. These relays are said to be entirely insulated from ground with insulation withstanding a minimum of 1500 volts. Field piece and armature are of annealed magnetic iron. Tinned phosphor bronze blades carry heavy fine silver points. All contacts are connected to tinned solder lugs. Contact combinations up to d-p. d-t. are available, with contact capacity up to 12.5 amps per pole at 110 volt, 60 cycle, non-inductive a.c. Contact rating for aircraft use is 8 amps at 24 volts d.c. Other voltages and contact combinations are available. On inductive loads, condensers are sometimes recommended to suppress arcing, their value being determined by test. Overall dimensions are 2½" × 1-9/16" × 1⅝". Weight (d-p. s-t. contacts): 5 oz.—*Guardian Electric Mfg. Co., 1621 West Walnut Street, Chicago, Ill.*

NEW! Wide-range frequency standard!

Measure frequencies accurately—in less time. New Western Electric instrument weighing only 150 lbs.—measuring only 28" x 21" x 15"—has all the features of the old bulky types *and more!*

Compact assembly gives frequency accurate to one part per million

Read these features of the Western Electric Frequency Standard Assembly.

(1) Frequency Standard and Harmonic Generator (lower panel) gives stable signal—harmonically rich or sinusoidal. Fundamental output frequencies of 100, 50, 20 and 10 kc. Harmonic output to 1000th harmonic. Accurate to better than 1 part per million without temperature control.

(2) Reference Frequency and Heterodyne unit (center panel)—crystal controlled oscillator circuit; modulator and amplifiers. 8 crystals give fundamental frequencies from 2 to 10 megacycles.

(3) Frequency Indicator Unit (upper panel) gives direct frequency reading of input signal from 0 to 100,000 c.p.s.

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Rubicon MULTIPLE REFLECTION galvanometers have recently been much improved through redesign of optical system. The definition of the line-image is now so sharp that readings can be estimated to .1 of a millimeter division.

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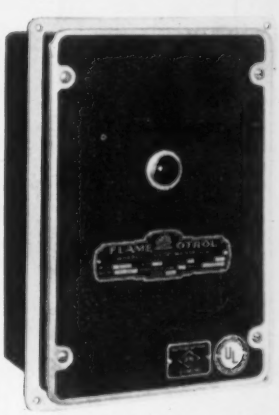

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Wheelco Instruments Co.
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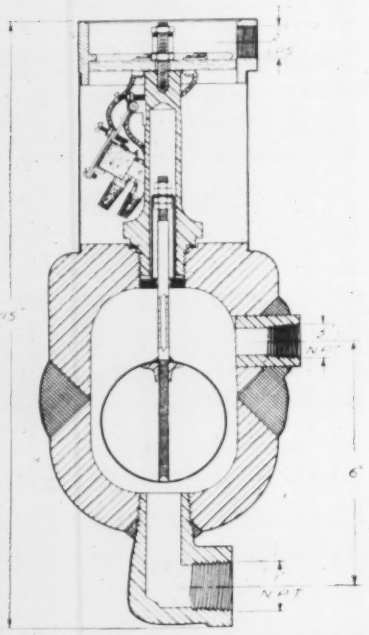
High-pressure Liquid Level Controller

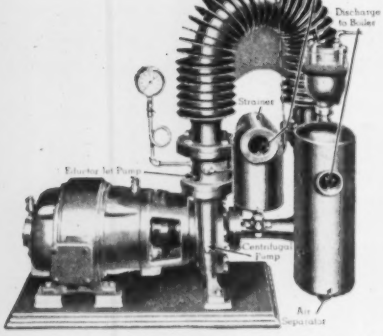
Newest "Magnetrol" unit, known as "Model H-5000," is for liquid level control or alarm purposes on extreme high-pressure applications, up to 5000 lbs./in.^{2}; tem-



perature —38°F. to 900°F. Electrical specifications: 15 amps. at 125 volts a.c.; 10 amps. at 250 volts a.c.; 6 amp. at 450 volts a.c.; switch action to customer's specifications. Operating differential $\frac{3}{4}$" min., $1\frac{1}{4}$" max.—*Fred H. Schaub Engineering Co., 325 W. Huron St., Chicago, Ill.*

High-pressure Condensate Return System

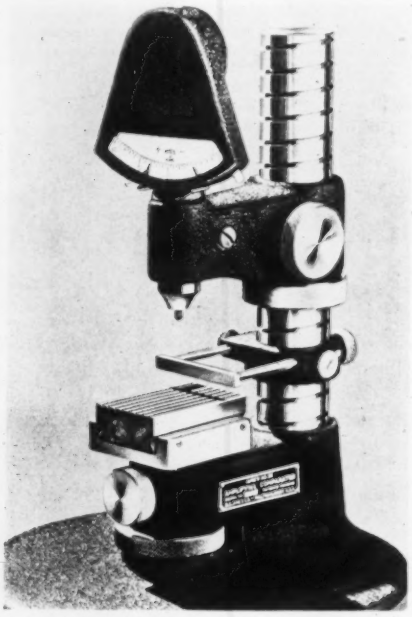
Essential engineering features of new Cochrane-Becker high-pressure condensate return system are: Eductor principle of operation insures thorough condensate and



air removal from process apparatus making increased production possible by maintenance of uniformly high temperatures. Then, after expulsion of air from closed circuit, condensate is returned to boiler at temperatures close to that of process pressure without flash loss and, it is said, "with remarkable fuel savings." A specially-designed centrifugal pump draws water from the thermo-fin priming loop and discharges it as a high-velocity jet through the jet pump nozzle. This jet, striking the returned hot condensate, induces condensate flow through mixing tube into thermo-fin priming loop. Additional volume of returned condensate introduced into constantly-filled loop results in discharge of an equal volume through air separator to boiler.—*Cochrane Corp., 17th St. and Allegheny Ave., Philadelphia, Pa.*

Amplifying Comparator

New "No. 26 Amplifying Comparator" is of extra-heavy construction with unusually large base, column, etc., to eliminate all spring. Fine adjustment of indicator is made



by moving dial with outside lever. Adjustable stop assembly helps locate work on hardened and ground anvil. Total height, 15", base diam. 11", total measuring capacity 6", fan head total range 0.002", distance from contact to front of post $3\frac{1}{2}$", anvils $2\frac{1}{8}$" × $3\frac{1}{4}$", special anvils to order. Approx. weight 40 lbs. Fan head is maker's "No. 1409 Dial Indicator" with ten-thousandths graduations about $\frac{3}{16}$" apart.—*B. C. Ames Co., Waltham, Mass.*

Galvanometer Shunts

(1) Ayrton-Mather Universal Shunts consist of a series of resistances so arranged that sensitivity of shunted galvanometer may be conveniently varied in accurately known ratios by a multi-contact rotary switch. Standard multipliers are 0, 1, 10, 100, 1000, 10000 and Infinity. Five models

are announced, with resistances of 3000, 10,000, 30,000, 50,000 and 100,000 ohms.

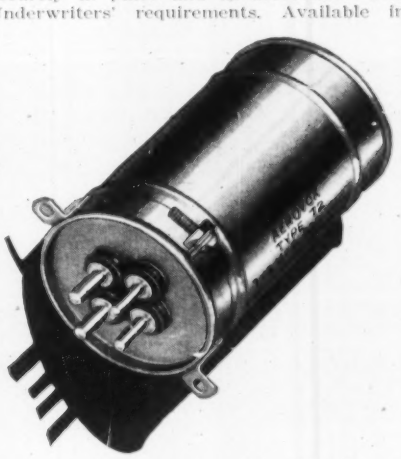
(2) *Compensated Ayrton Shunts.* These shunts are of the Ayrton type with the additional provision that the resistance of the shunted galvanometer as viewed by the current source is held constant for all multiplier positions. Among the circuits for which this type of shunt is particularly appropriate are those employing photosensitive elements in which the current output varies over very wide ranges. Although validity of multiplier values in compensated shunts is independent of galvanometer characteristics, each shunt can be resistance-compensated for only one particular galvanometer resistance. These units must, therefore, be constructed to order for the individual galvanometer with which they are to be used.—*Rubicon Co., Ridge Ave. & 35th St., Philadelphia, Pa.*

Voltage Regulator with Inverse-time Relay

New step-type voltage regulator is provided with a primary relay which has selective timing response. When a "small" voltage change occurs, it is said, the relay takes its time about operating so that if voltage comes back to normal "after a short while," the regulator is saved an operation. If the voltage change is "large," the relay speeds up, so that the regulator responds more quickly after the variation in voltage has occurred. New method thus differs from old method in which time delay is constant. New relay enables the regulator to give better service and insures against unnecessary tap-changing operations. Primary relay proper is similar in appearance to an over- or under-voltage protective relay, and is approx. 7" on a side. It operates on the induction-disk principle and has a damping magnet so that an inverse-time characteristic is obtained. Line-drop compensator is built into the relay and is set by means of a single knob. Relay being compensated for a wide range of ambient temperature, it can be used for pole-mounted installations.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Oil-filled Plug-in Capacitors

To electrolytic and wax-filled paper types, there is added a new "Series-72" oil-impregnated oil-filled capacitor with four-pin base that fits into a standard UX socket, as distinguished from the octal base of other plug-ins. Aluminum-sprayed tin-plate round can comes in 2", $2\frac{1}{2}$" and 3" diameter sizes, from $2\frac{1}{2}$" to $4\frac{3}{4}$" high, is provided with a mounting ring with lugs, so as to be held securely in place and in accordance with Underwriters' requirements. Available in



single-section units up to 16 mfd., and up to 4-4-4 mfd. in multiple-section units, in both the 400 and 600 v. D.C.W. ratings. New plug-in oil-filled capacitors are suitable for equipment used by Army, Navy, police, broadcast stations, public address and sound movie systems and said to be ideal for aircraft radio where duplicate receivers and transmitters are not available but where prompt servicing of single units is absolutely essential. UX base insures correct insertion of the capacitor into the circuit.—*Aerovox Corp., New Bedford, Mass.*

INCLINED MANOMETERS

FOR READINGS TO VERY SMALL FRACTIONS OF AN INCH!

TRIMOUNT builds a complete line of Inclinometers for extremely accurate readings of low positive and negative pressures. Long tubes with small differential permit readings to very small fractions of an inch. Typical instrument is a 48" test manometer with 2 tubes for reading from zero to 12" with calibrations of 1/100". Others have finer calibrations, any required range. All models have Pyrex tubes, leakproof gland packing and large wells visible for zero adjustment by external screw controlling displacer in well. Instruments are leveled by a micro screw adjustment. Write for full details, outlining your requirements.

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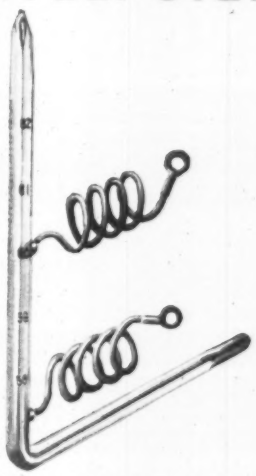

● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

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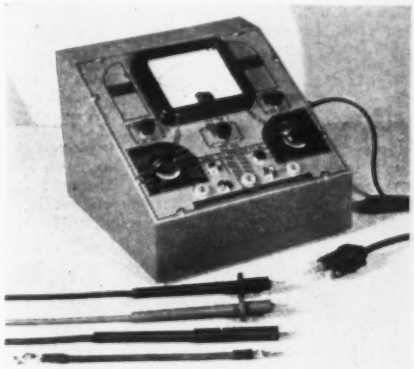
"Electronic" Multitester

New "Electronic Multitester Model 662," is an "electronically operated" high-sensitivity, multi-purpose instrument said to be particularly well adapted to requirements of industrial laboratories and testing departments. It provides a total of 27 measurement ranges: voltages, both a.c. and d.c., up to 6,000 volts; resistance to 1,000 megohms; capacities to 2000 μfd. The low ranges for each of these types of measurement are such that values as low as 0.1



volt, d.c., 1.0 volt a.c., 0.2 ohms and 30 μμfd can be read directly without interpolation or estimating fractional scale divisions. Any one of the 27 ranges is selected by means of two rotary switches, one of which selects the type of measurement desired, the other the numerical range. Indicating instrument is a 4½" square type d'Arsonval microammeter guaranteed accurate within 2% of full scale. Protection is provided to avoid possibility of burn-out or other damage to this instrument through improper range selection or attempting measurement of live resistors, etc. Vacuum-tube and power supply circuits are built-in and operating power is drawn from any 105-130 volt line. Applied voltages are held constant by means of a built-in electronic voltage regulator. Test leads and all parts employed in the high-voltage circuits are insulated for 15,000 volts. Four test leads: two standard high-voltage leads, one shielded lead with an extension adapter for use in measurements in critical vacuum tube circuits, etc., and a short lead for special uses. Metal cabinet is 9¼" wide, 9¾" deep and 7½" high.—*Radio City Products Co., 88 Park Place, New York City.*

Rheostat Cages

A variety of rheostat cages have been developed for use with maker's rheostats. Ventilated cages with perforated sides are

most generally applicable. Other types available are: dustproof cages, cages to house rheostats in tandem, explosion-proof cages, ventilated cages with one-half closed as a splash guard, and a laboratory type semi-enclosed table-top cage. Various types of terminals can be supplied.—*Ohmite Mfg. Co., 4835 Flournoy St., Chicago, Ill.*

Speed - - -

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Centrifugal Type

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Indicating Speed and Total Run.
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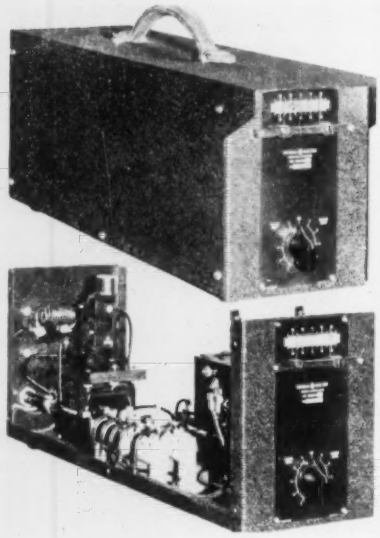
Magnetic Oscilloscope

New peak-reading portable magnetic oscilloscope has been developed primarily for use in resistance welding but may be applied as a supplement to other instruments used in trouble-shooting and in making installation adjustments. It is said to have "a high-speed response" to both current and voltage, made possible by the use of a permanent-magnet type of oscillograph galvanometer. Magnitude, symmetry, and uniformity of current wave are said to be revealed "quickly" by the length, position, and uniformity of a horizontal trace of light on the ground-glass viewing screen. A narrow light beam from an internal lamp impinges upon the tiny galvanometer mirror, the movements of which are reflected to the viewing screen. The instrument requires no reset time—a quick change from potential to current measurement is accomplished by turning a switch on the front of the box. The instrument is said to be almost entirely free from magnetic field interference. It weighs approx. 14 lbs., is 7" high, 6" wide and 17" long. It operates from 110-120-volt, 60-cycle current, using 25 watts.—*General Electric Co., Schenectady, N. Y.*

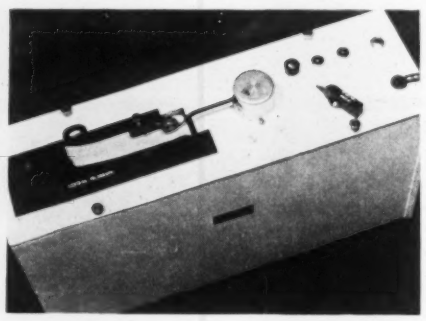


Voltage Regulator

Originally developed to be used in conjunction with maker's standard metallic rectifier electroplating units, new manually operated "B-L Voltage Regulator" is especially designed to provide a convenient and simple means for adjusting the voltage output of each individual or bank of rectifiers. It is available in a wall mounting cabinet for installation adjacent to the plating tank within convenient reach of the operator and away from the rectifier units. Regulator has 64 steps of adjustment, giving a voltage range from maximum down to one volt. Coarse control covers full range in eight steps; fine control provides eight steps for each step of the coarse control. In addition, regulator provides a start-stop station permitting remote control. On front of unit, and sealed against moisture and dust, are a voltmeter and an ammeter. It is said that by this method of control all the convenience of an individual tank rheostat is obtained but the rheostat losses of bus bar control are eliminated.—*The Benwood Linze Co., 1811 Locust St., St. Louis, Mo.*

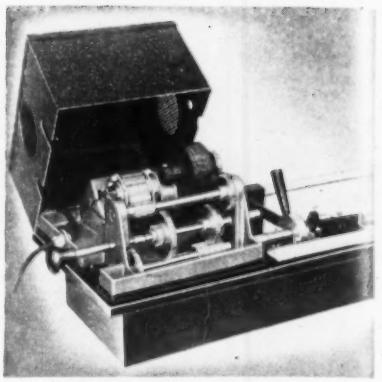
Direct-Writing Oscillograph

Low-frequency oscillograph employed in maker's Garceau Electro-encephalograph has been made available as a separate unit for physical and industrial research and is known as the "Garceau Velograph." It uses an electrically-sensitive recording tape upon which a stylus produces a trace instantly visible as a well-contrasted dark line. This trace is permanent, requiring no processing or developing. Oscillograph element is said to be exceedingly rugged, using no fragile crystals, no permanent magnets, no moving coils. Incorporated within the apparatus is a d-c. amplifier requiring an input of 30 volts peak-to-peak signal into a balanced impedance of 500,000 ohms for maximum deflection of 1" peak-to-peak of the trace. Oscillogram is substantially linear with voltage and with frequency over a range from 0 to approx. 74 cycles per second. It is critically damped by electrical means. Standard tape speed is 3 cm./sec. A power supply operating on 115 volts, 60 cycles, approx. 130 watts, incorporates the necessary rectifiers for the amplifier and polarizing fields. Instrument illustrated is a single-channel model. Multiple instruments with up to twenty recording elements are available. Applications include aeroplane vibration analysis, study of bearing pressures in rotating machinery and seismography.—*Electro-Medical Laboratory, Inc., Holliston, Mass.*



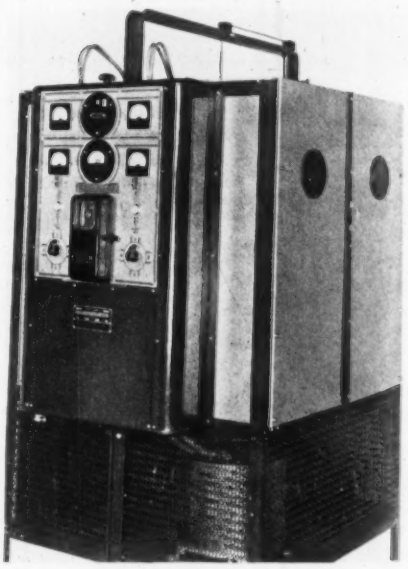
Ductility Tester

New ductility testing machine is said to present several new and exclusive features, complies with ASTM Designation D-113 for testing ductility of bituminous materials at speeds of ¼, 1 or 5 cm. per minute. Depth of 5" allows ample room for insertion of cooling coils or ice when conducting tests at reduced temperatures. Selective gear-drive mechanism is of automotive type, with all gears of bronze, on steel shafts. Bearings are oil-less type. Speed selection is virtually instantaneous, by means of a gear shift lever protruding from the gear-drive housing. Combination of ruggedness and accuracy is said to be achieved by utilizing a bronze lead screw, with Acme square threads free from sharp peaks to avoid screw thread delicacy. A single lead screw, instead of two, occupies little space in the trough, and is above water level, preventing agitation of water likely to impair observation of breaking point of sample. Being freely mounted at both ends, lead screw is not subject to binding or cramping stresses which would affect uniformity of pulling speed. After carriage reaches the 150-cm. limit, it automatically disengages the lead screw and comes to rest. Scale is divided in centimeters and millimeters; indicating pointer can be set to exact zero position at starting point. Machine can be suspended in a table top for flush mounting, or can be suspended in a tank for circulating liquid to maintain constant temperature.—*Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.*



Twin-Arc "Weather-Ometer"

New "Twin-Arc Weather-Ometer" is said to provide a dependable and accurate instrument for determining, within a few weeks, the result of months of weathering on fabricates intended for outdoor use: paints, varnishes, roofing materials, etc., is said to duplicate action of outdoor weathering by combining action of June sunlight, rain, heavy dew, and thermal shock. Increase in speed and efficiency over previously available equipment is said to be accomplished by the increase of active light at the specimen and the coördination of thermal shocks produced by cold water spray. Instrument is equipped with a cycle controller governing the light and thermal shock periods automatically. Cycle can be modified for various materials. No operator attention is required other than inspection of samples and reloading of the arc units every 24 hours. Total cost of carbon and current consumption amounts to $1.20 for a 24-hour day. All standard Weather-Ometers now in use can be converted into the new Twin-Arc Testing Unit.—*Atlas Electric Devices Co., 397 W. Superior St., Chicago, Ill.*



"Strap-on" Limit Control

New limit or operating control for hot water heating systems is said to be unusually easy to mount as the trough-shaped base permits a snug fit in direct contact with hot water pipes. Mounting requires only fastening of a metal strap to hold the control to either horizontal or vertical pipes, as satisfactory operation is obtained in any position. Mounting base and thermal element are one and the same part in order to simplify design and to assure immediate response to changes in boiler water temperature. Temperature cut-out setting is made without removing the cover. Available for low- or line-voltage circuits, and in direct- or reverse-action models.—*Perfex Corp., 500 W. Oklahoma Ave., Milwaukee, Wis.*

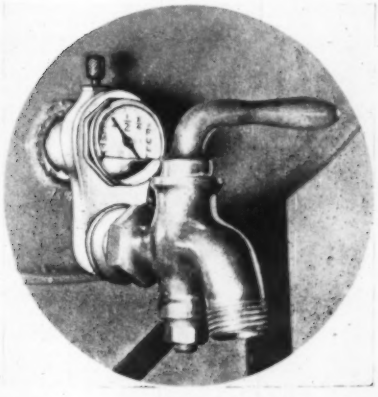
Shatter-proof Rheostats

New type of maker's All-metal Rheostat for aircraft and ordnance use where durability to withstand bomb and gunfire concussions, as well as dependability to meet conditions of high humidity and other temperature extremes are prime essentials, is

announced. Instead of ceramic insulators new ordnance type units have Bakelite insulators, have a 50% lower temperature rise for equal size in other types, are available in 25- and 50-watt sizes to meet the 200-hour salt-spray test requirement. Covers are available to protect units from dust and dirt.—*International Resistance Co., 401 N. Broad St., Philadelphia, Pa.*

Level Gage for Drums

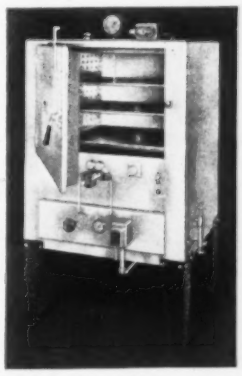
New "U-C" Level Indicator" for 55-gallon storage drums consists of a cork float mounted on a wire rod, the level of which is indicated on a dial installed on the external fitting, said fitting fashioned to receive the user's faucet or spigot. Guessing



and tapping are eliminated. Indicator is simple to install, easily transferred, works on all liquids of a non-corrosive nature.—*U-C Level Indicator Sales, 828 North Broadway, Milwaukee, Wisconsin.*

Constant-temperature Cabinet

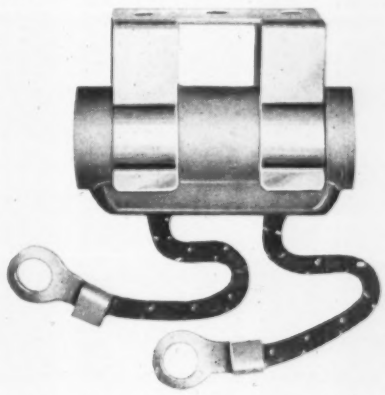
New series of explosion-proof constant temperature cabinets, heated by steam and approved by Underwriters' Laboratories, Inc., are for use in hazardous locations, Class I, Group C and Group D, in which flammable volatile liquids, highly flammable gases, mixtures or other highly flammable substances are manufactured, used, handled, or stored in other than their original containers. Basically, cabinet is a "Precision-Freas" mechanical convection model in which a motor-driven turbo-blower produces a forced circulation of heated air across the working chamber. Explosion-proof features are classified under two headings: (1) Com-



plete absence of exposed contacts, electric controls, switches, or wiring terminals; (2) Installation of safety catches or release latches on doors, for instant opening under pressure of an explosive burst which might occur inside the cabinet; also special venting provisions for exhausting dangerous gases. Steam, instead of electricity, is used for heating. Temperature range is 35 to 150°C. Oven can be operated at any steam pressure between 0 and 100 lbs. saturated, but operating temperature is governed by steam pressure. Oven is safeguarded against excessive temperatures by a 100-lb. pressure release valve. Four standard sizes are available.—*The Precision Scientific Co., 1736-54 N. Springfield Ave., Chicago, Ill.*

Unbreakable Mercury Switch

New Bacon Mercury Switch is a simple metallic cartridge in two parts, sealed together and pressed into a tube of insulating material then sealed again with lead wires



(any length) soldered direct to the metallic cartridge which is filled with inert gas under pressure. Contact is made and broken in the mercury itself "with a minimum degree of tip." Switch is available in single- or double-throw types.—*Bacon Electric Timer Corp., 4513 Brooklyn Ave., Cleveland, Ohio.*

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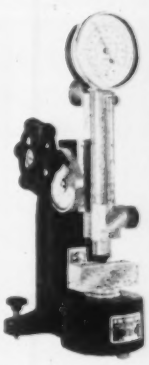

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Simple Pressure Regulators
Principal Types and Their Characteristics

By H. C. McRAE
Research Engineer, The North American Mfg. Co., Cleveland, Ohio

A PRESSURE REGULATOR may be defined as an automatic valve which controls the pressure of a fluid at a given point in the flow circuit, regardless of the quantities of flow or the pressure variations at other points in that circuit. This pressure may be constant or variable.

The purpose of controlled pressure is sometimes for a controlled force. In a hydraulic application, for example, the force from a piston is a direct function of the pressure of the liquid on the piston. More often, the purpose of controlled pressure is a controlled rate of flow. There are many applications of this principle in the gas industry and chemical processing. Probably the most common example is in the use of a regulator in the gas line to a hot air furnace to hold the rate of gas flow constant. Another function of the pressure regulator is to reduce a high-pressure supply to a more convenient lower pressure.

Regulators may be divided into two classes: those which control inlet pressures and those which control outlet or discharge pressures. The mechanism is much the same for

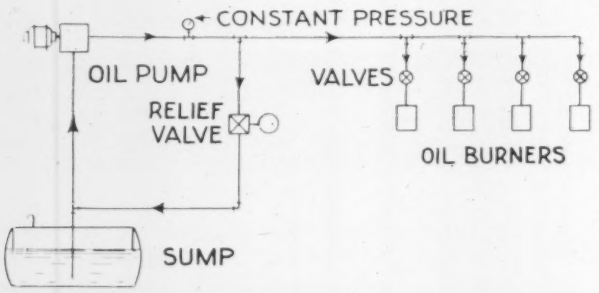


Fig. 1

the two, the only difference being that for inlet pressure regulators the diaphragm is connected with the supply pressure and tends to *close* the valve when the pressure drops, restoring it again to normal; while for outlet pressure regulators the diaphragm is connected to the discharge side and tends to *open* the valve when the pressure drops, bringing it back to normal again.

Fig. 1 shows a typical circuit using an inlet regulator which is more commonly called a relief valve. The pump is a constant-flow positive-displacement type. The pressure ahead of the valves on the oil burners must be held constant from minimum to maximum flow. The relief valve "bleeds off" the oil not being used by the burners on lower flow rates, and maintains a constant pressure for them.

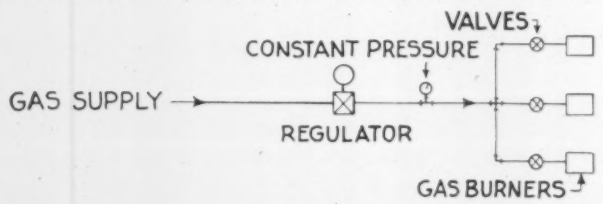


Fig. 2

Fig. 2 is an illustration of an outlet pressure regulator used ahead of a system of gas burners. The valves ahead of the burners are set individually. By maintaining a constant pressure ahead of these valves, the flow rates remain constant. The regulator must respond to either an inlet pressure variation or a change in gas demand by the burners. To maintain a constant outlet pressure, the valve in the regulator must move towards the closed position if the inlet pressure should increase or if the demand should decrease.

A regulator in its simplest form consists of a valve, a pressure gage and an operator as shown in Fig. 3. The operator watches the gage and moves the valve in the

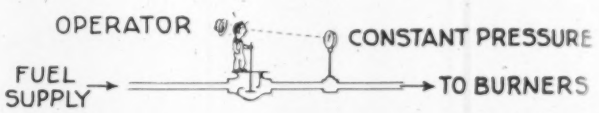


Fig. 3

proper direction to maintain constant pressure. In practice the operator is replaced by a diaphragm, one side of which is loaded with a pressure—spring or weight—to correspond to or equal the pressure desired, and the other side connected to the pressure region which is to be controlled, as illustrated in Fig. 4. Four different ways are shown to control the outlet pressure:

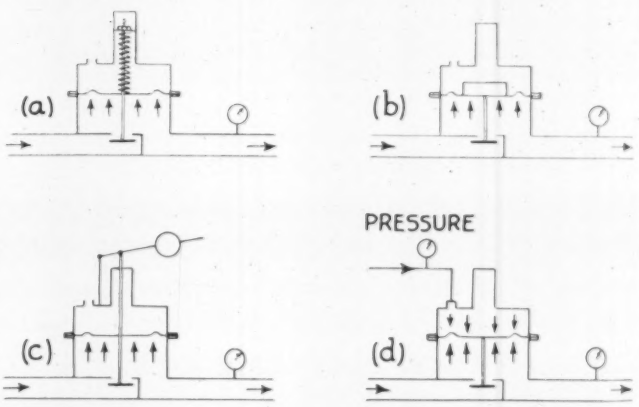


Fig. 4

(a) A compression spring furnishes the force downwards necessary to balance the force (area times pressure) due to the outlet pressure on the bottom side of the diaphragm. Since the spring may be adjusted, the pressure may be varied.

(b) A weight balances the pressure.

(c) A weight with an adjustable lever arm balances the pressure and hence different pressures may be obtained. The weights have the advantage of giving a constant force for any valve position, while the force from the spring varies with valve position.

(d) The pressure may be controlled by using an external pressure from another source.

In all of the above examples the principle is the same, that is, if the outlet pressure should increase it will push the diaphragm upwards and, at the same time, close the valve sufficiently to bring the pressure back to normal.

On further analysis of Fig. 4, it is seen that the valve head itself acts as a small diaphragm. The inlet pressure is on the bottom, and the outlet pressure on top. The resultant force is upward. It is obvious, then, that as the inlet

pressure increases, the outlet pressure will fall off slightly to offset the increased force. The larger the valve or the smaller the diaphragm, the greater is the error produced by a change in supply pressure.

Regulators designed for reducing high pressures to relatively low pressures can stand a large pressure drop and hence the valve opening is small. The error from the pressure on the valve head is sometimes further reduced by connecting the valve and the diaphragm through a lever arm which steps down the force from the valve as shown in Fig. 5.

For relatively small reductions in pressure, the valve must be large to get sufficient capacity through it. In this

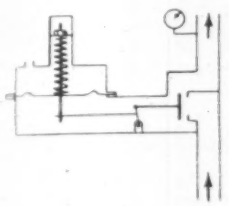
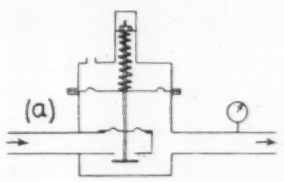


Fig. 5



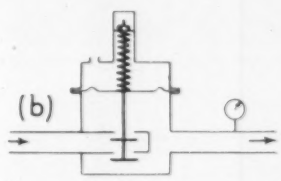


Fig. 6

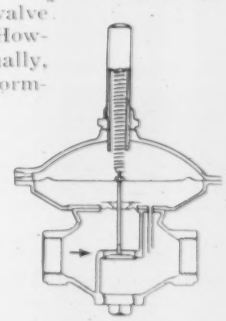


Fig. 7

case, either a "balanced" valve or a "balancing" diaphragm is used. The latter is illustrated in Fig. 6(a). The difficulty with this is that the effective area of the diaphragm changes with valve position and hence is not always "balancing." Fig. 6(b) shows the "balanced" valve. There are two disadvantages with this type of valve: both valves will not shut off exactly the same time, causing leakage in the closed position, and furthermore, these valves are not exactly balancing since in one case the valve head is upstream from the valve opening and in the other case it is downstream from the valve opening. Special shapes of valve heads have been developed which more nearly balance but still tend to leak in the closed position.

When the diaphragm and valve assembly move to find a new position of balance, the inertia of the moving parts may tend to carry the valve beyond this position. Immediately the diaphragm will reverse the valve and again move it beyond the proper point. This may continue periodically. "Hunting," as this phenomenon is called, is sometimes of large enough magnitude to render the regulator useless for part of its range. The greater the change in pressure for a given valve stroke, the greater the chance for undesirable hunting. The motion may be dampened to cure hunting, but care must be taken to avoid any frictional resistance on the valve assembly when at rest as this would introduce an error.

Fig. 7 shows a common type of regulator known as a zero governor or atmospheric regulator. Since the outlet pressure is held at zero gage, flow is obtained by applying suction to the outlet connection. There are five forces on the valve assembly, the resultant of which must be zero for the valve to come to rest. The equation of these forces is as follows:

$$\underset{\text{Tension Spring}}{K(a+x)} + \underset{\text{Main Diaphragm}}{K_1A_1(P_0-P_a)} + \underset{\text{Balancing Diaphragm}}{K_2A_2(P_i-P_0)} + \underset{\text{Valve Head}}{A_3(P_0-P_s)} = \underset{\text{Gravity}}{W}$$

where

K = Spring rate—ounces per inch of movement
a = Length spring is stretched with valve in closed position—inches
x = Valve opening—inches
K_1 = Main diaphragm coefficient—dimensionless
A_1 = Main diaphragm area—square inches
P_0 = Outlet gage pressure—ounces per square inch
P_a = Gage pressure on top of main diaphragm—ounces per square inch (zero if vented to atmosphere)
K_2 = Balancing diaphragm coefficient—dimensionless
A_2 = Balancing diaphragm area—square inches
P_i = Inlet pressure—ounces per square inch
A_3 = Valve area—square inches
P_s = Average inlet static pressure on valve head—ounces per square inch
W = Weight of the assembly—ounces

Ideally, the forces of gravity and the tension spring should cancel each other, while the forces on the balancing diaphragm and valve head also should neutralize each other. This leaves $K_1A_1(P_0-P_a)=0$ or $P_0=P_a=0$. Actually, these forces only cancel out for one valve position, usually the closed position. However, by studying these forces individually, it is readily seen how regulation performance can be improved.

The tension spring is adjusted to balance the weight of the parts when the valve is in the closed position. As the valve opens, x increases, causing the spring tension to increase. By using a long spring with a relatively low value of K and by limiting the valve to a small stroke, the variation in the force is minimized. The lighter the weight of the parts, the smaller the spring rate for a given spring length.

The pressure on the bottom of the valve head is the outlet pressure, but the pressure on top is not exactly the inlet pressure except for the closed position. Some of the supply static pressure is converted to velocity pressure as the fluid passes through the valve opening. Both the spring force error and the valve head error tend to make the outlet pressure decrease as the valve opens or as the rate of flow increases.

A diaphragm coefficient is defined as the actual force obtained on the valve stem divided by the calculated force from the product of the diaphragm area and the differential pressure. From fluid mechanics it is known that the force on a diaphragm, regardless of the shape, is the differential pressure times the projected flat area. However, part of this force is wasted on the plates which hold the diaphragm at its periphery, while the useful part of this force is transmitted to the valve shaft. The coefficient is increased by the use of plates clamped on either side or both sides of the diaphragm. As the valve opens, the diaphragms move away from their original positions and the coefficients decrease. This means that the balancing diaphragm error tends to increase the outlet pressure as the valve opens.

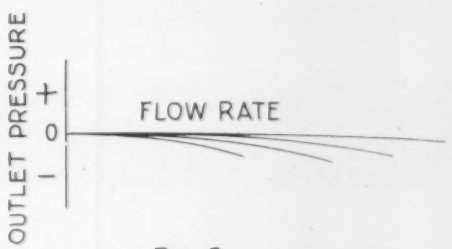


Fig. 8

The larger the main diaphragm, the less P_0 must deviate from P_a to correct for the errors previously mentioned. Typical performance curves are shown in Fig. 8. Each curve represents a fixed supply pressure.

Sometimes another error is purposely introduced into the mechanism to compensate for the errors existing. This is

(Continued on Page 59)

A New Mercury Rheostatic Method

By K. A. OPLINGER

Westinghouse Research Laboratories, East Pittsburgh, Pa.

MANY novel controllers have resulted from the fundamental idea of controlling the current in an electric circuit by using some form of "contact making" device. In the simplest arrangement, a single pair of contacts may be used to change the resistance of a control circuit. Minimum circuit resistance is obtained with the contacts closed; maximum resistance with the contacts opened. If the contacts are vibrated, the effective resistance of the circuit may be varied between the maximum and minimum value in a manner to give practically continuous control. This form of single-contact amplifier has been described in a previous paper.[1]

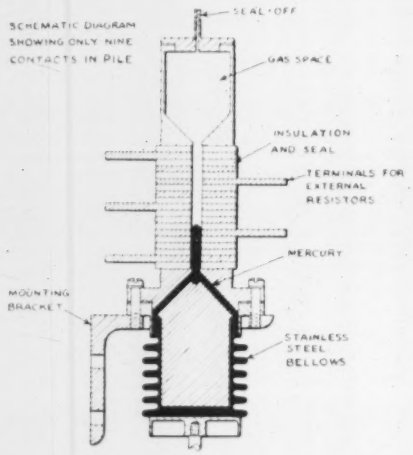


Fig. 1

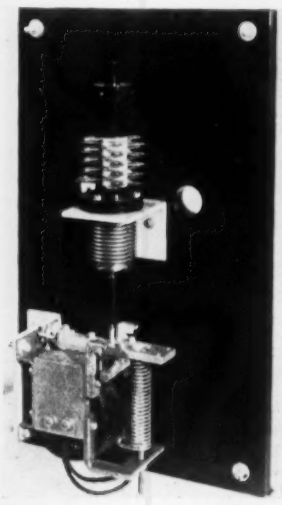


Fig. 2

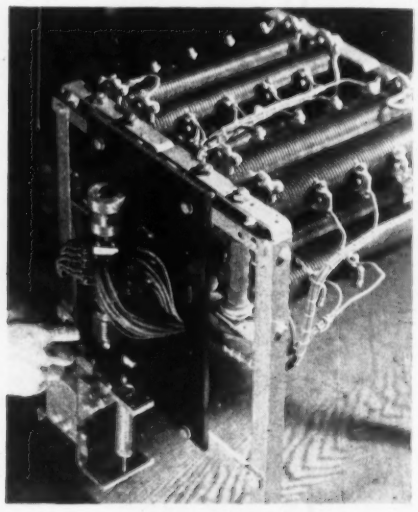


Fig. 2A

The amount of power which can be handled by a single pair of contacts is, of course, limited by the current and voltage of the circuit. By using more contacts it is possible to control larger amounts of power. The rheostat is an example of such a design. However, in most regulating and control systems, the ordinary rheostat cannot be used because of such factors as large power input, frictional and hysteresis forces, or the large inertia and displacement of moving parts. Novel rheostatic control members have been designed to remove the above limitations. For example, in the "Silverstat" regulator a large number of silver contacts are so arranged that they may be operated by a small force and a small travel.[2]

A new design of rheostatic element has recently been developed which uses a large number of mercury switches so arranged that the force and travel required to operate the switches is very small. For convenience in describing this new design, it has been called a "Mercurystat."

A schematic of the contact arrangement of the Mercurystat is shown in Fig. 1. A forty-step element with electromagnetic driver is shown in Fig. 2. Referring to these two figures, the contacts are small flat terminals, each having a central hole. These terminals are assembled with a thin insulating spacer between each pair of terminals as shown. At the bottom of the terminal assembly, a stainless steel bellows, with a plug to reduce its volume, serves as a reservoir for the mercury. Displacement of the bellows raises and lowers a column of mercury which shorts out, or cuts in, sections of an external resistor connected to the contact terminals. A gas chamber at the top of the column prevents any appreciable change in pressure from the slight changes in volume caused by the bellows displacement. The entire assembly is hermetically sealed by a special process so that the interior of the Mercurystat can be pumped out and charged with an arc-reducing gas such as hydrogen. It is then sealed off from the atmosphere to eliminate all contact maintenance.

By making the ratio between the area of the bellows and the area of mercury column as large as practicable, only a small displacement of the bellows is required to short out all contacts. For example, in the forty-step Mercurystat shown in Fig. 2, the terminal assembly, which is about two inches high, can be shorted out by a bellows displacement of fifteen thousandths of an inch.

The power which can be controlled by this new mercury rheostat is fixed by the interrupting capacity of the contacts and by the internal losses of a given design. The internal losses of the Mercurystat are due to the resistance of the terminals and the mercury column; also to the contact drop between the mercury and terminals. The large number of steps makes the contact duty in the Mercurystat much less severe than in the ordinary mercury switch operated at line voltage. To obtain some idea of the power capacity, a small forty-step Mercurystat as shown in Fig. 2 was used for life tests in a 220-volt d-c. circuit to vary the current from 12 amps. minimum to 30 amps. maximum. After completing five million cycles of operation the contacts showed practically no signs of wear.

In many regulating systems it is desirable to have the rheostatic member operate from an electrical stimulus. In such cases an electro-magnetic driver as shown in Fig. 2 may be used. To provide a frictionless pivot, the driving arm, which operates the bellows, is mounted on cross springs. A calibrating spring is attached to one end of the driving arm and on the other end an iron armature is mounted. By proper shaping of this iron armature, the negative stiffness of the driver can be made to match the positive stiffness of the Mercurystat and calibrating spring. Extremely small changes in force or in coil current are now required to move the Mercurystat through its range. This is shown by the typical response curves of Fig. 3. When adjusted for 1% droop, a change of 0.05 watt in the drive coil will operate the Mercurystat through its entire travel. The change in output power may be, say, five kilowatts s

(Continued on Page 58

[1] "Recent Developments in Speed Regulation," C. R. Hanna, K. A. Oplinger and S. J. Mikina, *A.I.E.E. Transactions*, Vol. 59, 1940, pages 692-700.

[2] "Recent Developments in Generator Voltage Regulation," C. R. Hanna, K. A. Oplinger and C. E. Valentine, *A.I.E.E. Transactions*, Vol. 58, 1939, pages 838-44.

Control of Stockrooms, Inventories, etc., by means of Special Weighing Devices

By H. I. MAYCOCK

Industrial Field Engineer, Toledo Scale Co., Toledo, Ohio

IN all businesses where thousands of small parts are daily shifted from the stock room to the assembly line, inventory appraisals and accountings necessarily have to be closely regulated, especially today when metals are at a premium.

A convenient method of keeping records is based on the use of a weight control system. Scales are being increasingly utilized not only in terms of numbers but in specialization. Where in the past one general scale had been assigned to handle a multiplicity of weighing jobs, two or three or perhaps four scales have been installed, each a different type and designed for a specific industrial control job.

This specialization is obviously desirable. While weight itself may be applied in a limitless number of ways, a scale like any other mechanism of measurement has its limitations. It subscribes to its function as an instrument of weight most efficiently when by its structure and capacity it is adapted to the task it is to perform. A scale, in other words, must be scaled to the weighing assignment.

Fig. 1

A well-equipped and adapted weight control system has been established by Harley-Davidson now under contract with the government for the production of scouting motorcycles, for weighing and counting the great variety of fittings that flow each day to and from the stockrooms, production, assembly and other departments. Aside from the equipment purchased to take care of war work, this company has, through the past quarter century, constantly added new scales to better its weight control system. Scales now in use range from heavy-duty floor scales to precision scales sensitive to 0.0005 lb.

In Fig. 1 floor scale equipment may be observed in action. This machine has a total capacity of approximately three tons, with, however, 1-lb. graduations to insure close accuracy even on heavy load weightings. Its high capacity plus the 1-lb. graduations fit it for a variety of requirements, from loads of less than a hundred pounds up to its full capacity.

This machine also serves as an automatic counting device. This counting application is based on the multiplication of the levers in the scale: a small weight at the end of a long lever will counterbalance a much larger weight on the platform itself. In the illustration, each of the bolts that the operator drops into the large ratio pan offsets the weight of ninety-nine bolts on the platform. Each bolt placed in the smaller ratio pan counterbalances nine on the platform. As a result, if there are twenty bolts in the large pan, seven in the small, and the scale indicator has been brought to zero, the total count of the parts is 2070. Tedious hand counting is eliminated.

In the foreground of Fig. 2, an intermediate size scale is shown. It is a predetermined weight type designed for loads up to approximately 200 lbs. Its over-under zero indication provides maximum indicator travel per pound, hence greater sensitivity than without this device. The double ratio counting mechanism on this machine operates on the same principles as on the large floor scale.

The background of the same illustration shows the sensitive fan scale apparatus used to count or weigh the parts too small for either the floor or bench scale. This equipment is used where small deviations (in fractions of ounces) must be discerned. This model demonstrates particularly well the versatility of the modern scale. This machine possesses three distinct weighing ranges. It can be adjusted so that it will weigh and count loads as heavy as twenty pounds. Chart graduations here are by 0.05 lb. Also it provides a capacity of 1 lb. by 0.005 lb. Or, it may be instantly adjusted to weigh 0.1 lb. by 0.0005 lb.

The Coleman Lamp and Stove Company, Wichita, Kansas, also possesses a weighing system for production and stock records on the many parts that go into the manufacture of its regular and other products. Their equipment includes floor scales, portables, bench scales and other modern types,

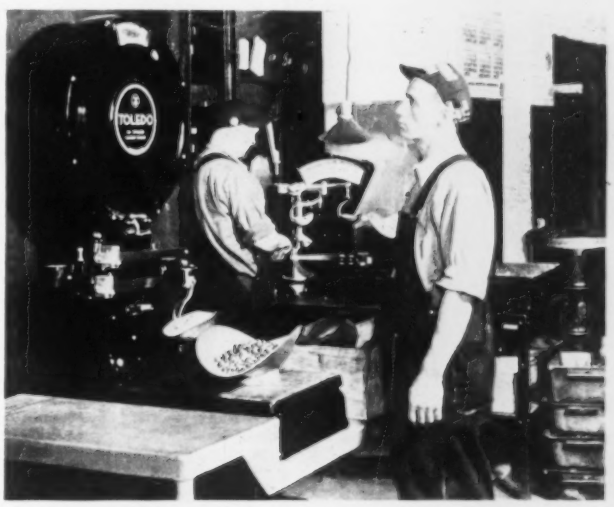


Fig. 2. Foreground—Predetermined-weight bench scale. Background—Three-range scale.

many of which are equipped for counting. In the foreground of Fig. 3 an operator is checking the weight of a load of fittings on a predetermined-weight portable weigh-

(Continued on page 60)

Maintenance and Servicing of Electrical Instruments

By JAMES SPENCER

Foreman, Instrument and Relay Testing, Westinghouse Elec. & Mfg. Co., Newark, N. J.

CHAPTER II

(Continued)

A-C. VOLTMETERS

The voltmeters to be discussed at this time are those that operate on the electrodynamic, repulsion and induction principles. These instruments are made in both switchboard and portable types. In this section, however, only the switchboard type will be dealt with. Switchboard instruments include the large switchboard, medium switchboard and miniature panel types which are made for both projection and flush mounting. Their uses are as the names imply. They are designed and calibrated for alternating-current circuits, but some of them can be calibrated for direct-current circuit application with equal accuracy as will be pointed out later in this writing.

Voltage is the pressure that causes current to flow in a closed circuit. The volt is the accepted unit of electrical pressure or, as the dictionary defines it, the unit of electromotive force or difference of potential. Ohm's Law states that the voltage is equal to the current in amperes multiplied by the resistance in ohms, that is, volts = amps × ohms. From this we can see that if one ampere is flowing through a resistance of one ohm the pressure or voltage of the circuit is one volt.

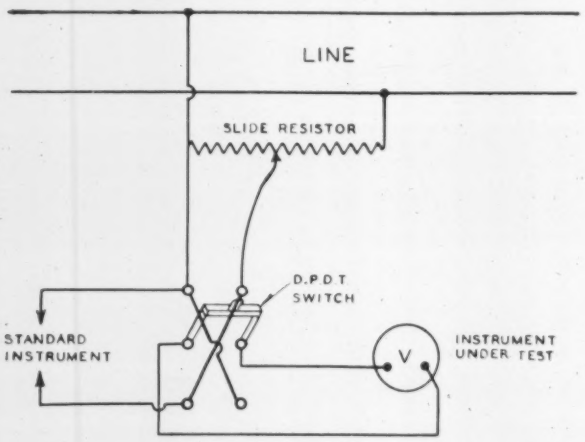


Fig. 22. Connections for testing an electrodynamic type instrument on direct current, with a double-pole double-throw switch for taking reverse readings.

In view of the foregoing we can say that the voltmeter is an instrument for measuring electrical pressure or potential difference existing between any two points of an electric circuit.

Again, it will be apparent that a voltmeter is essentially a low-capacity ammeter (milliammeter) with a resistor in series with its coil, adjusted to the value of the volts, according to Ohm's law. The millivolts are as required to give a force or torque sufficient to operate the spring to full-scale pointer deflection. Take away the resistor and you have an equivalent milliameter.

Principles of Operation of A-c. Voltmeters

Dynamic electricity manifests itself in two forms, one called direct current which flows in a unidirectional line; the other called alternating current because as it flows it is constantly changing from positive to negative and back, as shown in Fig. 1 of this chapter.* We learned that the permanent-magnet moving-coil type instrument (Chapter I) measures direct current only and that the induction type instrument (Fig. 4 of this chapter) measures alternating current only. Before studying the induction instrument in detail we shall discuss the electrodynamic type that measures both a-c. and d-c. electricity.

When measuring a d-c. circuit with an electrodynamic instrument, readings must be taken in both directions through the instrument, to eliminate any error due to stray fields. If a stray magnetic field acts in unison with the fixed coil in one direction it will oppose it in the other. The average of the two readings is nearest to the correct readings. See Fig. 22 for connections when testing a voltmeter on direct current.

The electrodynamic principle depends on the attraction and repulsion of parallel wires carrying currents in the same or opposite directions. Wires carrying currents in the same direction are attracted to each other and repel each other when the currents flow in opposite directions. See Fig. 2 of this chapter. The moving coils and stationary coils of the electrodynamic voltmeter are connected in series and wound with a large number of turns of fine wire, making the instrument sensitive to small currents. When connected across a high-voltage line, a series resistor is used to reduce the voltage across the instrument. The stationary and moving coils are connected in such a way that they may move with respect to each other, the moving coil being caused to turn. A mechanical torque produced by two spiral springs

*The first part of this chapter, with Figs. 1 to 21, dealt chiefly with a-c. ammeters. It appeared in the September 1941 issue of *Instruments*.

A Contribution to the War Effort

IN normal times it is inadvisable for users of electrical instruments (except users such as utilities with fully-equipped service laboratories) to do any work which involves opening up the case. Before 1941, the only articles on adjusting and servicing instruments which we accepted for publication were on Bourdon gages and other comparatively rugged measurement and control devices. And all we published on the subject of repairs and rebuilding was our stock editorial (reprinted every two or three years) saying "Let the factory do it."

But this national emergency has created a shortage of electrical instruments, so that even plants enjoying priority have to wait. The top shelves of stockrooms are being searched for old instruments. "Irreparable" instruments are being "repaired." And —perhaps most important—all instruments in use must be maintained in good condition . . . by the users. Hence the crying need for this serial—the first and only one of its kind.

NOTICE TO STUDENTS IN INDUSTRY

Chapter I (Direct-current Instruments) appeared in the August 1941 issue of *Instruments*, pages 226-240.

The first part of Chapter II (A-c. Instrument Definitions, A-c. Ammeters) appeared in the September issue, pages 255-268.

Chapter III (A-c. Wattmeters), December issue, pages 394-403.

Chapter IV (Summary of A-c. Types), December issue, page 404.

Chapter V (Instrument Transformers), December issue, pages 405-408.

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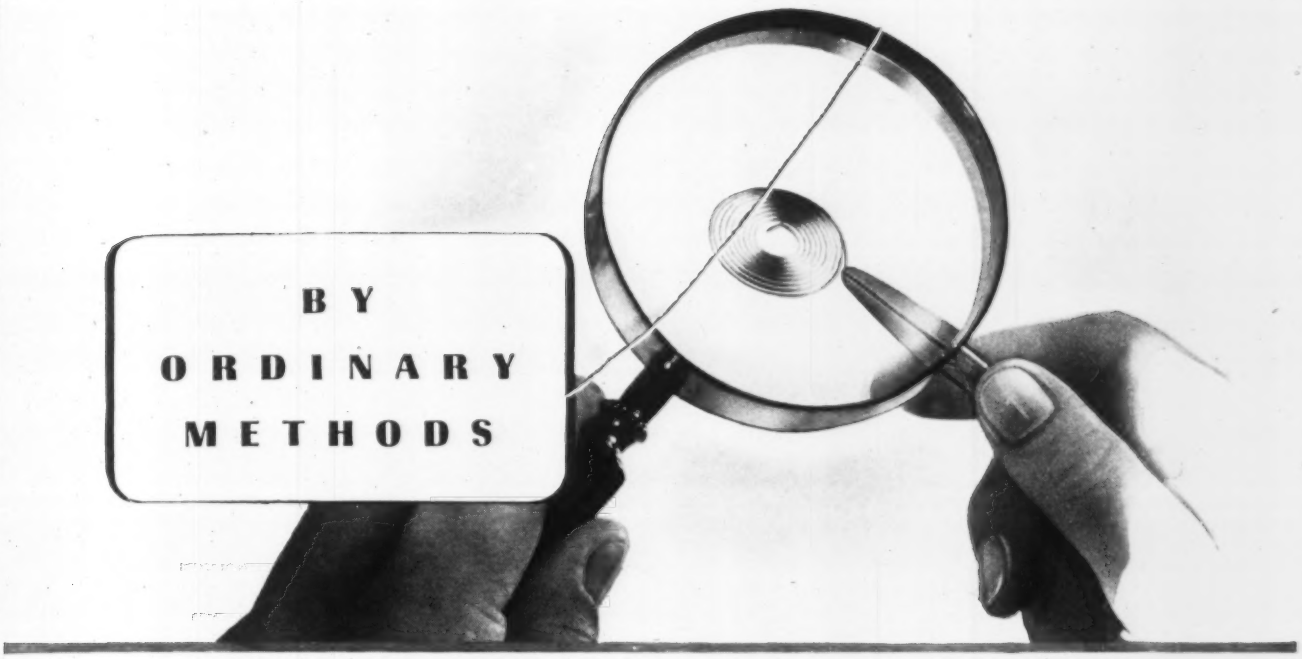
It is expected that this serial will be completed and brought out in book form before June.



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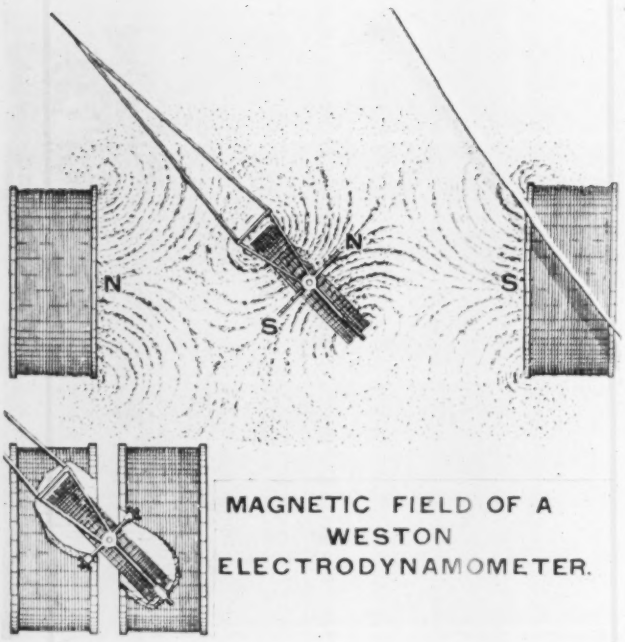

MAGNETIC FIELD OF A WESTON ELECTRODYNAMOMETER.

Fig. 23. Lines of force are made visible in this diagram (courtesy Weston Elec. Instrument Corp.) to illustrate the operating principle of the electrodynamic instrument. See also Figs. 2 and 5 of this chapter.

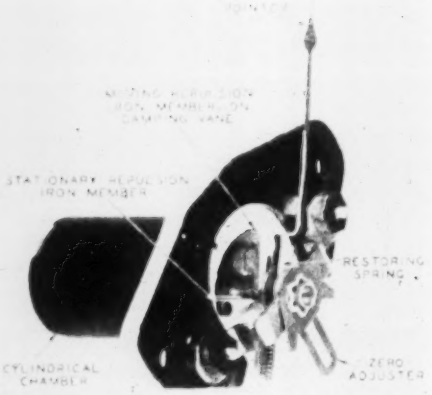

Fig. 24. A Westinghouse repulsion iron instrument mechanism. See also Figs. 3, 6, and 25 to 29 inclusive.

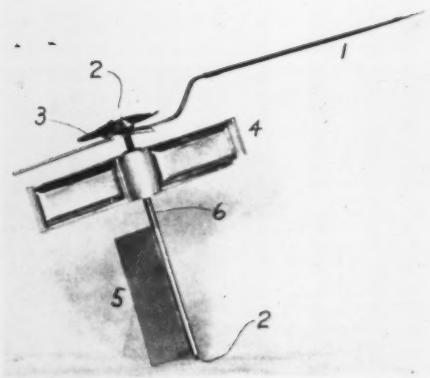

Fig. 25. Moving-iron type voltmeter or ammeter movement complete showing:

1. Pointer—usually made of aluminum
2. Pivots—hard polished steel
3. Control spring—phosphor bronze
4. Damping vane—aluminum
5. Moving iron vane
6. Element shaft

opposes the electrical torque and brings the pointer to rest where the two balance. The springs are wound in opposite directions to compensate for changes due to temperature or other causes. When this type of instrument is used on d-c. circuits the current in the moving coil produces a magnetic field which always opposes that of the stationary coil. See Fig. 23. On a-c. circuits, as the current changes in the moving coils it also changes in the stationary coils, therefore these magnetic fields always oppose each other. This instrument is made dead beat by the use of an aluminum vane rotating in an air chamber compressing the air as it moves, making a good damping device. (Damping will be discussed in a later chapter.)

When voltage is applied to a repulsion type instrument, the two iron vanes are magnetized by the flux around the coils. See Fig. 3 of this chapter. As the two vanes are in one plane (nearly) and magnetized by the same field, they are magnetized in the same direction; hence we have two north poles at one end and two south poles at the other. As the two magnets tend to repel each other and as one is mounted on the shaft and free to move, they tend to separate. This rotation of the moving member is retarded by the action of a spiral spring. Both the large and miniature type voltmeters are air-damped, the large type having an aluminum damping vane and rotating in a chamber similar to

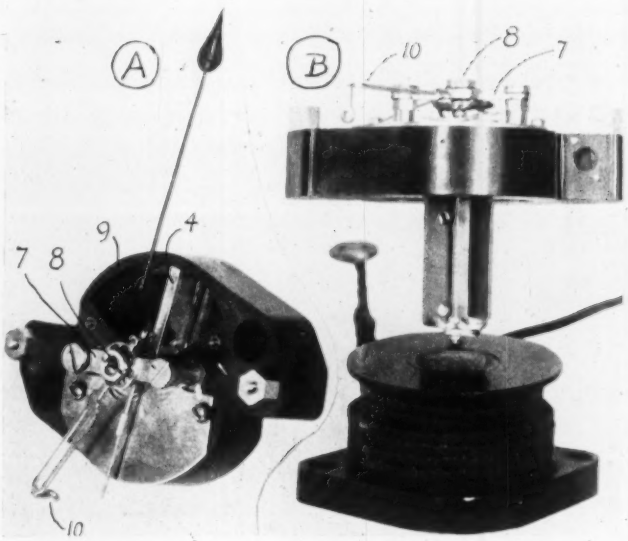

Fig. 26. Voltmeter or ammeter movement assembled in sub-base showing one-half of damping chamber covered.

7. Top bridge
8. Jewel screw
9. Damping chamber
10. Zero adjuster

that of the dynamometer type, while the small instrument utilizes the moving iron vane and the closed mounting bracket for this purpose. See Fig. 24.

The principle of operation is similar in both ammeter and voltmeters of the induction type; a detailed explanation has already been given earlier in this chapter.

For reasons of simplicity and sturdiness the moving iron type is quite invariably used for switchboard type a-c. voltmeters and ammeters, in preference to the electrodynamic type. This is also the case for a-c. portable voltmeters, except such as are used as secondary or transfer standards for calibrating other a-c. instruments by comparison to the d-c. methods of standardization.

Thus electrodynamic portable ammeters and voltmeters may be calibrated in the laboratory with standard voltage cells, standard resistors and potentiometer sets and then used with equal accuracy for calibrating other a-c. instruments.

The electrodynamic principle is generally used for both portable and switchboard type of wattmeters, power factor meters and frequency meters.

CONSTRUCTION

Moving-iron Type

A typical voltmeter movement would consist of a pointer, moving coil, or disk, or iron vane, a damping vane, springs and balance weights mounted on a shaft at the end of which are hard steel pivots. See Fig. 25 for a view of a repulsion element. The pivots rotate in jewels or bearings which are generally of sapphire, depending on the type of instrument. As the movement rotates it carries the pointer across a scale that is calibrated in volts to agree with a standard of known accuracy. Internal connections of the various types of voltmeters are shown in Figs. 4, 5 and 6 of this chapter.

The large flush and projection type voltmeter of the repulsion type is built with pressed steel base and case, and a hard-rubber or molded sub-base. A stationary coil is wound with copper wire in a cylindrical form, the center being an open core as shown in Fig. 27. The moving element consists of a vane of non-residual iron (see below) mounted on the shaft of the instrument that also carries the damping vane, pointer and spring. See Fig. 25. The stationary iron is mounted on a bracket that is attached to the damping chamber housing in such a position that when the pointer is at zero the two iron vanes are very close to each other and parallel as in Fig. 26B. The damping chamber is similar in construction to that of the electrodynamic type. Hard steel pivots and sapphire jewels are used.

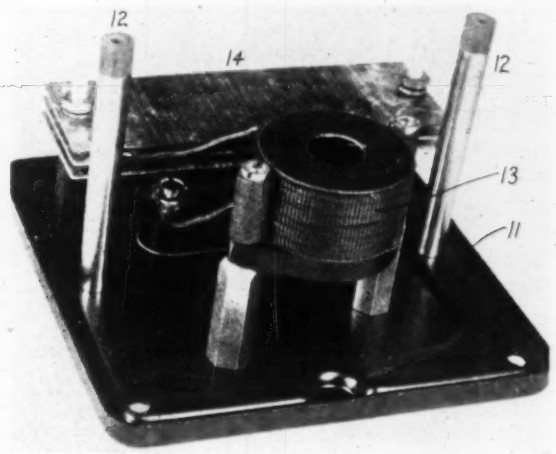

Fig. 27. Showing the stationary coil mounted on the base with resistance cards for use as a voltmeter.

11. Base
12. Dial posts
13. Field coil
14. Resistor cards—for voltmeters

The term "non-residual" perhaps requires a further explanation. All iron or steel when magnetized presents the phenomenon of hysteresis which can be compared to viscosity or stickiness in mechanics. Thus steel tends to retain some of its previous magnetic state after the magnetic field strength is changed. This property can be either increased or decreased at the will of the steel research specialist. If greatly increased we have the familiar "permanent magnet steel." If almost totally eliminated by other special alloying and treatment, we obtain the non-residual variety, the use of which largely avoids the fact that otherwise moving iron instruments would read low on increasing values of d-c. and high on decreasing values.

Fig. 30 shows schematically the moving-iron type mechanism used in a concentric-scale instrument. The permanent-magnet moving-vane method of damping is utilized in this type instrument, but is not shown in the sketch. An instrument embodying this type mechanism is shown in Fig. 31 with its cover removed. The external resistor used with this instrument is shown attached to the base.

The miniature type instrument differs in construction from the large type in size and parts. The stationary iron

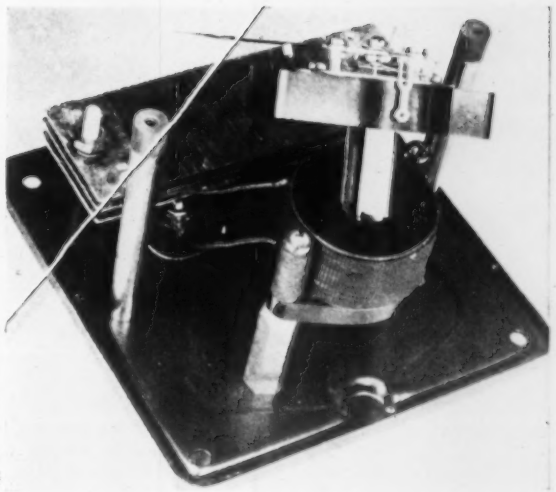

Fig. 28. Showing the movement partly removed from its position in the open core of the field coil.

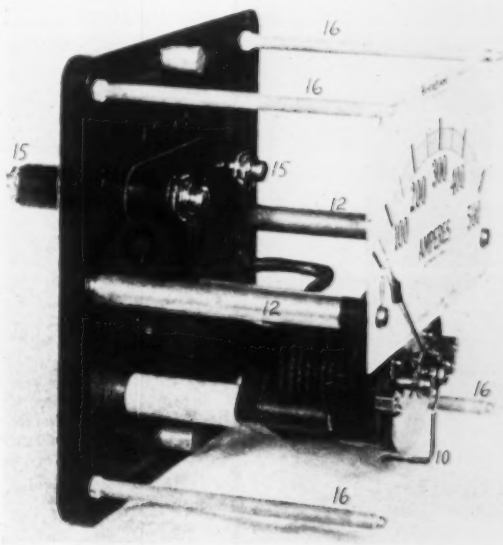

Fig. 29. Repulsion type ammeter with case removed showing scale, pointer, movement and internal construction.

15. Terminals
16. Cover studs

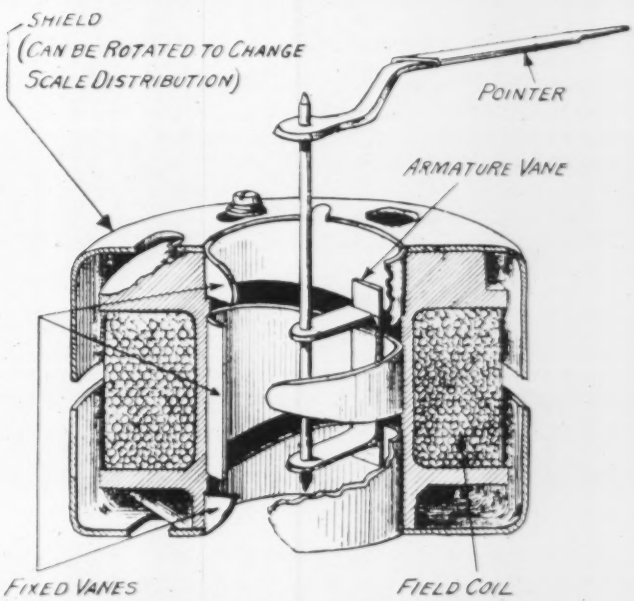

Fig. 30. Mechanism of General Electric Co.'s concentric-form a-c. voltmeter or ammeter, Type "AB-10."

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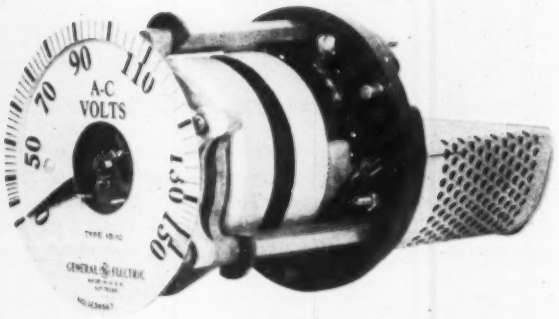

Fig. 31. This is not only a complete instrument mechanism (of a General Electric concentric-scale voltmeter) but since the assembly includes scale, resistor, resistor housing, etc., it is a complete instrument minus the case and cover.

is a rod and the molded element bracket also acts as the damping chamber. See Fig. 24.

Electrodynamic Type

The switchboard electrodynamic type voltmeter usually has an iron base and cover that serve to mount the element and make the instrument dust-proof. These parts being iron also serve as a shield for the instruments to protect the

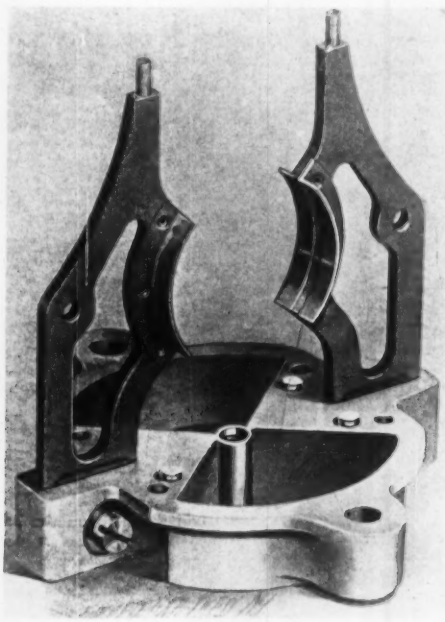

Fig. 32. Sub-base of electrodynamic type voltmeter with supporting brackets and damping chamber, one-half of which is shown closed. (Weston.)

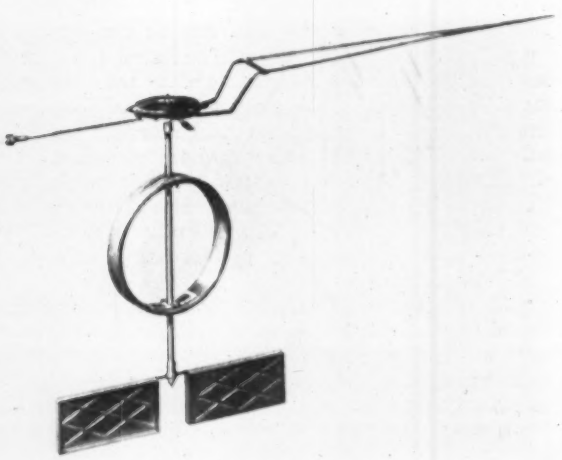

Fig. 33. Voltmeter moving-element assembly, showing all the moving parts of the instrument. (Weston.)

element from being affected by stray fields. The coils, both moving and stationary, are connected in series through springs that also act as the retarding element. A typical mounting for these parts as shown in Fig. 32 is on a brass frame, set into a hard rubber or molded sub-base that serves as a means of breaking the magnetic circuit of the frame, holds the lower jewel and serves as a damping chamber. The moving coil, as in Fig. 33, is mounted on a shaft at each end of which there is a hard steel pivot that turns in sapphire jewel bearings mounted in the frame (upper) and the sub-base (lower). The shaft also carries the aluminum pointer that traverses the scale to indicate the voltage of the line being measured. At the lower end of the pointer there are three balance arms on which are mounted weights for balancing the moving element. An aluminum vane on the lower end of the main shaft rotates in the chamber of the sub-base to produce damping. See Fig. 34.

The cut-away view, Fig. 35, is typical of the magnetically damped electrodynamic mechanism. This view clearly shows the construction, the relative positions of the moving and stationary coils, and the position of the aluminum damping vane on the element shaft. The aluminum vane, shown mounted just below the top spring, moves between the poles

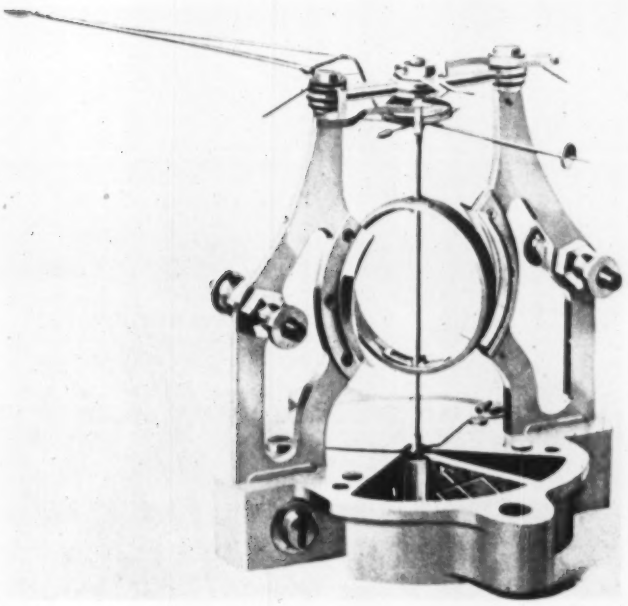

Fig. 34. Weston voltmeter mechanism with stationary coils and one of the damping chamber covers removed.

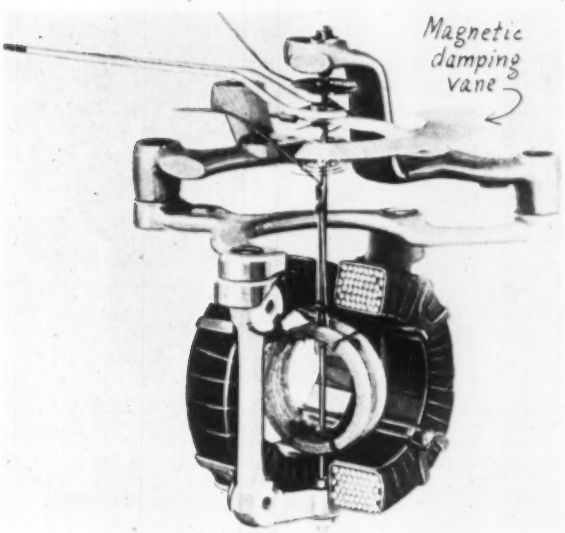

Fig. 35. General Electric Co.'s electrodynamic instrument mechanism with magnetic damping vane. Parts cut away to show moving coil.

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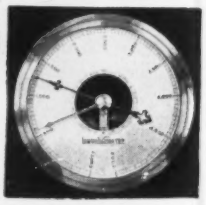

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of a permanent magnet (not shown in the figure) which results in damping of the fluctuations of the moving element.

Induction Type

The construction of the induction type voltmeter is similar to that of the induction type ammeter, except for the higher resistance coils and the use of the resistor. See the section on Induction Type Ammeter earlier in this chapter.

Inspection and Test

An outline of the overall test given an electrodynamic voltmeter follows.

With the instrument in the horizontal position face up, set the pointer on zero and balance in three vertical positions as shown in Fig. 5, 6 and 7 of Chapter I. Then connect the instrument and resistor to a circuit in which the voltage can be varied; adjust full scale by changing the resistance of the internal or external resistor, or by the spring method as outlined under ammeters; next, check the angular half scale point by applying approximately two thirds of full-scale point as a check on scale distribution. If the scale distribution is wrong, shift the coils with respect to the pointer in order to correct. A pointer position adjustment is generally provided in the pointer support. After

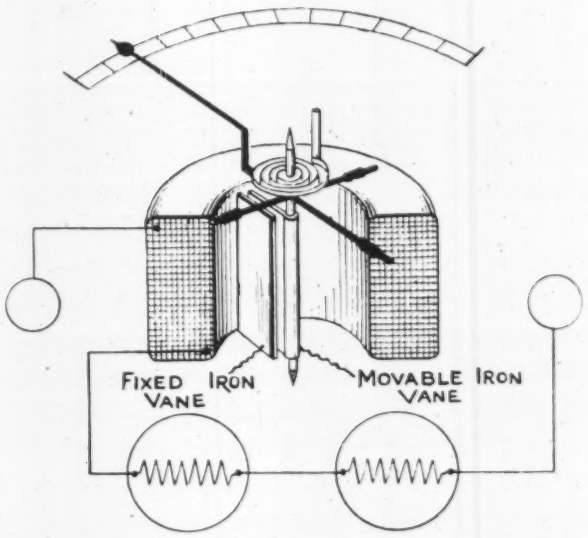

Fig. 36. Schematic diagram of repulsion type instrument mechanism.

giving the instrument a good mechanical inspection (as will be outlined in the next paragraph) all points on the scale should be checked with a suitable standard instrument of known accuracy connected in parallel with the instrument under test. It may be necessary to replace the scale entirely, with an unmarked or blank scale, and then apply new scale markings in the manner to be explained in a succeeding chapter.

All instruments should be carefully checked for friction, end play and balance. Examine the springs and see that convolutions do not touch one another. See that the pointer passes ends of scale before hitting the bumpers or pointer stops.

See that all connections are properly adjusted, well soldered and of good appearance. Screws and nuts should be tried to see that they are secure. The instrument should be cleaned and free of loose materials that sometimes become lodged in a case.

Ground test—Apply 1500 volts between terminals and case for one minute for standard 150-volt instruments, unless manufacturer's information specifies otherwise. Instrument of higher voltage should be ground tested by following the A.I.E.E. rule of 1000 volts plus twice the capacity of the instrument.

The large repulsion type voltmeters can be calibrated by either changing the series resistance or by adjusting the control spring. The test of this type instrument other than just pointed out is similar to that of the electrodynamic type. The small repulsion type, such as shown in Fig. 24, s

adjusted by turning the iron rod that is mounted on a cam which projects through the bottom of the element frame. By changing the position of the rod we alter a distance between the stationary and moving iron and hence affect the torque of the instrument. After the adjustment of the spring on the large type, the zero setting is obtained by shifting the small lever that acts as the anchor for the inside convolution of the spring.

The same inspection is given this type instrument as is given the electrodynamic type. Ground test voltages as outlined in A.I.E.E. rules also apply to this instrument.

Internal connections of the repulsion vane type voltmeter are shown in Fig. 36.

The calibration adjustments of the induction type voltmeter are made by changing the external resistor or by changing the spring strength. For inspection specifications see explanation under induction type ammeters.

The internal connections of the induction type voltmeter are similar to those of the induction type ammeter.

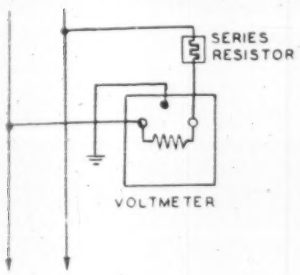

Fig. 37

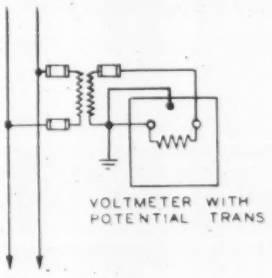

Fig. 38

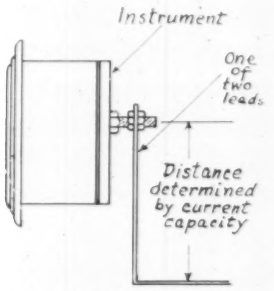

Fig. 39

As shown in Figs. 37 and 38, the voltmeter and the series resistor are either connected directly across the line for lower voltages or through a transformer for higher voltages.

The following are a few of the items that may affect calibration accuracy of an instrument.

Repulsion type instruments are affected by both a-c. and d-c. fields if not heavily shielded. Lead-in wires to high-current ammeters should be run straight down from the instrument before making bends. See Fig. 39. Instruments should not be mounted on steel panels unless calibrated for use in this manner. That is, if an unshielded instrument is to be used on ⅛" steel panel, its accuracy will be reduced if it is not calibrated on a steel panel of the same thickness. The thickness of panel is important to the calibration.

This type of instrument may be used on d-c. circuits but, for greatest accuracy, reverse readings should be taken and averaged. The range of frequency on which these instruments may be used is usually specified by the manufacturer. Most repulsion type instruments are accurate on frequencies between 15 and 125 cycles. Below or above these frequencies the accuracy of the instrument may be reduced. Ammeters of this type are practically free of temperature errors between 15 and 35°C. (60 and 95°F.).

Moisture in the instrument could cause corrosion and rusting of the various parts of the element, impairing the accuracy of the instrument and reducing its useful life. This can be avoided by keeping the instrument tightly covered and the dust- or moisture-proofing parts well intact. With changes of temperature, the coils have a heating action which causes expansion and contraction of the air within the instrument drawing the outside air into the in-

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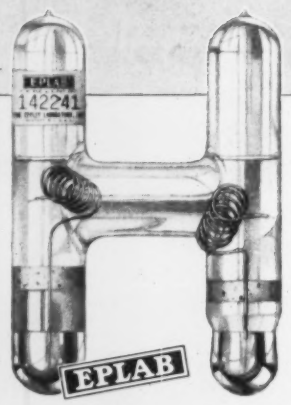

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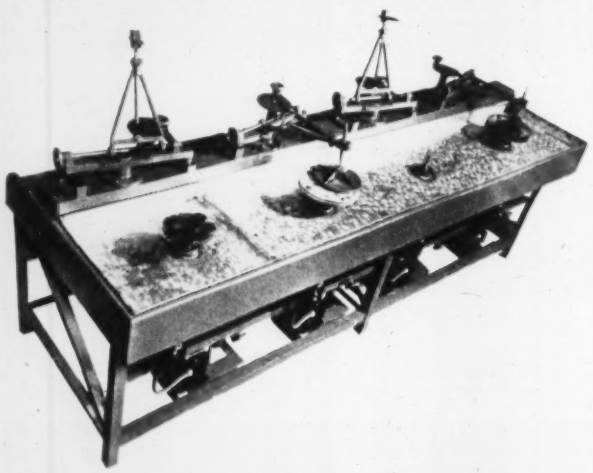

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strument. If the outside air has a high moisture content, and the case is not moisture-proof, the air that enters the instrument will deposit its moisture on the metal parts.

Cleaning the case of an instrument is a good habit to form, but can cause calibration errors if the glass is rubbed with a cloth and not grounded afterwards. If the glass is rubbed severely, it may take on a static charge that will affect the deflection of the pointer at zero or up scale. Oftentimes we reset zero due to a static charge on the glass, hence we introduce errors throughout the scale. To eliminate this fault, neutralize the static condition by touching the glass with your fingers after rubbing.

Electrodynamic type instruments are affected by external fields of the same frequency, hence they should be shielded for best results. They have a much higher frequency range than the repulsion type instrument, usually within guaranteed accuracy on frequencies up to 500 cycles. On d-c. circuits, however, best results are obtained by taking reverse readings and averaging the same. Most electrodynamic instruments are enclosed in iron or steel cases and therefore are not subjected to steel panel mounting effects. The moving-coil type instrument is more delicate than the other types and should be handled and used more carefully.

Possible Defects in electrical instruments may be listed under two major headings, namely, *mechanical errors* and *electrical errors*. For simplicity and convenience of explanation, the two major division may each be further sub-divided into two secondary headings: *Instruments Failing to Operate* and *Instruments Operating Inaccurately*. Mechanical errors are mentioned first because they are the cause of the majority of instrument troubles.

Let us analyze a few of the mechanical causes of errors and the effects they produce. Probably the first item that comes to the mind of an instrument man is *Friction*—and rightly so, because friction probably causes more instrument troubles than any other single factor. When an instrument is found to have friction the first thing the repair man should do is to check all visible moving parts for sufficient clearance. A few of the most common faults in this catagory are:

spring convolutions touching,
pointer rubbing on dial,
springs touching adjacent parts.
balance arms touching stationary coils,
lint on coils causing drag on moving coil, and

Springs loose on shaft or holders give the appearance of friction when tapping the instrument as the pointer takes a new set when the spring slips. A check of end play will indicate whether the friction is caused by insufficient end-to-end motion of the shaft (tightness of pivots in jewels).

Loose end play may also cause variations in readings, and shifting of element balance.

Other points to examine in analyzing friction troubles are:

damping vane clearance,
dirt in damping chamber,
pivots (broken, flat or distorted) and
cracked or dirty jewels.

Loose pointer on shaft, pivots loose in shaft and jewels loose in jewel screws are also points to be checked to ascertain the cause of friction.

Other mechanical points to check when inaccuracies exist in an instrument are:

balance,
spring set,
zero shift,
pointer bent,
moving coil distorted,
element or dial shift, and
pointer too far away from dial causing parallax errors.

Electrical errors found in instruments are, first, those that cause the instrument to indicate inaccurately and, second, those that produce total failure of indication. Under the first heading we have poor connection (mechanical or solder) that cause resistance changes in the circuit. Grounds and partial shorts tend to decrease the field strength of the coils by changing the effective ampere-turns of the coils.

Open shunt circuits not only cause the instrument to read high, but also causes the element coils to take the full load and may effect a burn out. Wrong connections, either internal as in all electrodynamic type instruments or external as in wattmeters, may cause the instrument to read backward, partly forward or no reading at all. To correct this condition see explanation under connections of each of the three named instruments.

Abnormal temperatures, external fields, shorted resistors, steel panel influence and static effects on glass cover are other items that cause inaccurate indications of the instrument.

Instruments of the repulsion type are usually calibrated and applied to circuits of frequencies not higher than 150 cycles. Electrodynamic type instruments are usually applied to circuits of frequencies not greater than 500 cycles. If these instruments are calibrated on 60 cycles it will be found that their calibration is affected when applied to circuits having higher frequencies than these limits.

When repairing or handling an element of the repulsion vane type, care should be exercised not to bend the iron vane, as it tends to destroy the anealing of the iron and introduce residual magnetism in the vane.

Loose terminal connections results in variable readings, especially in the wattmeter, and may give the appearance of being friction as the indication of the pointer may change slightly when the instrument is tapped.

Instruments Failing to Operate.—The electrical cause may be an open coil or series resistor; there may be external circuit or the element may be completely shorted.

In checking or calibrating instruments having metal cases, be sure to check with the cover on the instrument as the cover affects the calibration slightly.

If non-shielded instruments are suspected of being within an effective external magnetic field, a definite point of indication should be observed and the instrument position changed several times to note any change of reading.

The chart, Fig. 8 of this chapter, shows the uses to which the electrodynamic type instruments may be put; the accessories used with the different classes of instruments; and the frequency range over which each kind of measurement may be made with desirable results.

A few points to be checked to guard against errors of observation are: pointer high above scale, short pointer, pointer tip bent, angle of observation, glare due to illumination, poor lighting and shadows. Some of the measures taken by instrument manufacturers to prevent such errors are: mirrors under pointer; indirect lighting; antiparallax scale and pointer; and non-glare glass.

As regards pointer length, a good gage for the target type would be to have the tip terminate within one-quarter to three-quarters of the distance between the scale divisions. Always try where possible to eye the pointer from directly behind it to avoid parallax errors.

New High-power Testing Facilities*

SHOWN in the photograph [front cover] is the central control desk of the new high-power laboratory at the Westinghouse East Pittsburgh works. In this testing station, facilities are now available for testing short circuits of 2,000,000 kva. In addition, the previous current limit of 3200 amperes on a 132-kv. three-phase circuit has been extended to 7500 amperes. Test voltages have been raised from 230 kv. to 345 kv. three-phase and from 264 to 396 kv. single-phase with mid-point grounded, thus amply exceeding present transmission voltages.

The laboratory is in effect a power station delivering a short circuit output comparable with that on large power systems. Unlike a large public utility, however, the laboratory carries no continuous load and a short circuit is a normal instead of an abnormal condition. The flexibility of

*Abstract of portions of "High-capacity Circuit Breaker Station" by J. B. MacNeill and W. B. Batten, presented at winter convention of American Institute of Electrical Engineers, New York, week of January 26, 1942.

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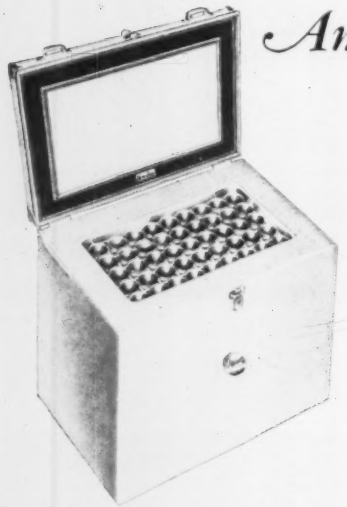

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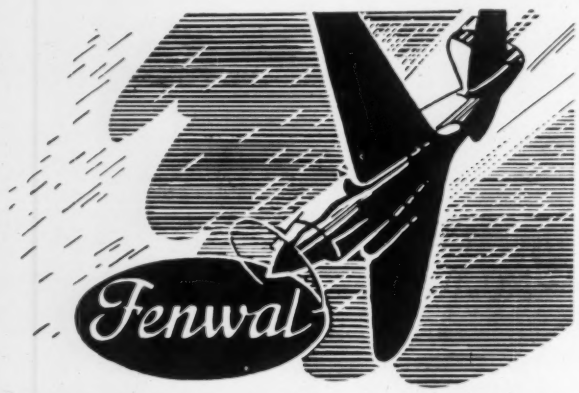

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Operation of the facilities is controlled from the central control desk separately housed about 500 feet from the generator sets and transformers. The desk contains the necessary indicating instruments, protective relays, annunciators, and test jacks for checking all measuring and control circuits. The arrangement is such that a single operator can completely observe every test. An oscillograph records simultaneously voltages, amperes, arc energy, trip coil current, breaker travel and pressures generated in the breaker tank.

A sequence drum controls the actual test operations once the voltage and current limiting reactors have been set to the desired valves. Since two sequence drums as well as two oscillographs are available it is possible to quickly shift from one setup to another without changing the measuring and control currents.

A New Mercury Rheostatic Method

(Continued from Page 46)

that the power amplification, or ratio of output to input, is 100,000. By adjusting the calibrating spring to give a less perfect matching between negative and positive stiffnesses, different amounts of droop can be obtained as shown by the curves in Fig. 3. The linearity of the output current can be conveniently adjusted by grading the external resistors connected between contacts.

The effect of changes in temperature and atmospheric pressure upon the Mercurystat depends upon design proportions and how it is applied in a regulating system. For example, if the Mercurystat is used in a system where the

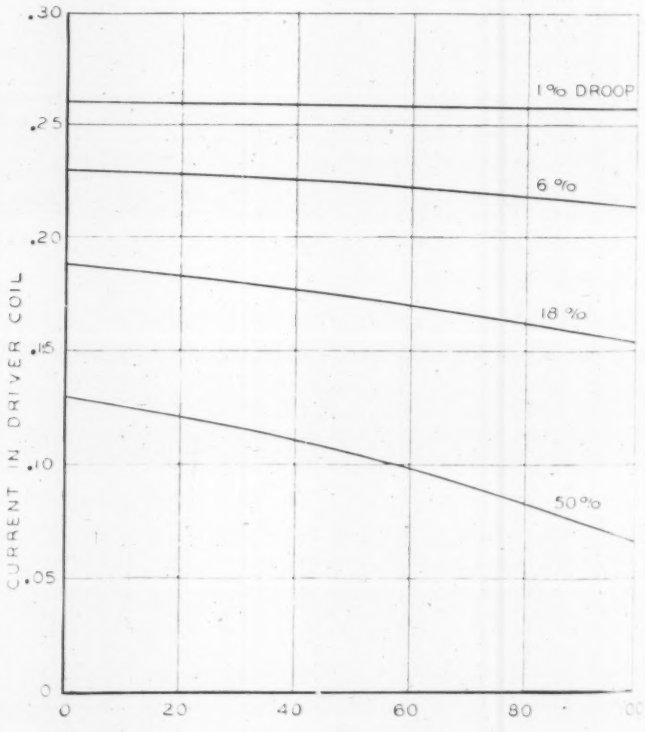

Fig. 3

regulator has a 1% droop and changes in temperature and atmospheric pressure are such as to cause the Mercurystat resistance to change, say, 10%, the regulator would correct for this change with a resulting error of 0.1%. If desired, the small errors introduced by changes in atmospheric pressure may be completely eliminated by the use of a second sealed bellows attached to the driving arm.

Temperature errors can be kept low by proper design so that in any given application the effect of changes in temperature is usually negligible.

Applications for a controller of this type will be apparent to those familiar with regulating systems and need not be discussed here. Devices of this type have been classified by M. F. Behar as "prime relays"[3] and their characteristics and applications have been described in a previous publication.[3] Several typical applications of the Mercurystat were given in a recent paper.[4]

[3] "Classification and Characteristics of Prime Relays," M. F. Behar, *Instruments*, Vol. 13, 1940, pages 364-69.

[4] "A New Mercury Rheostatic Element for Regulation and Control," K. A. Oplinger, *A.I.E.E. Transactions*, Vol. 60, 1941, pages 846-49.

Simple Pressure Regulators

(Continued from Page 45)

done by impressing a false lower pressure on the main diaphragm than actually exists in the outlet chamber, using a venturi effect on the pressure tap.

If P_a is controlled externally to bring P_0 to the proper value at all times by means of another regulator, the other regulator is called a "pilot" regulator. The valve in the pilot regulator controls P_a on the main regulator but does not control any pressure on its own diaphragms. The outlet pressure from the main regulator is led to the pilot diaphragh as shown in Fig. 9. The main regulator has little to do with the accuracy of the control, as the pilot regulator

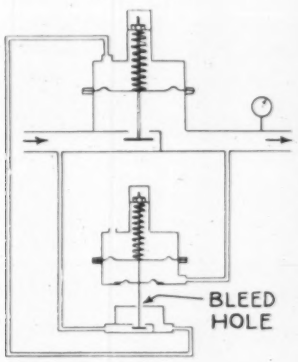

Fig. 9

furnishes the "brains." Since the actual flow through the pilot valve may be extremely small, the valve is small and operates in a narrow range about an average balancing position, whereas a main regulator must have a large valve for sufficient capacity as previously discussed.

Pilot control is more subject to hunting than single regulators because two mechanisms must come to balance *at the same time* or one will move the other out of balance.* The pilot regulator is often built into the main regulator body. Instead of the pilot valve receiving pressure from the same source as the main regulator, it may have a more powerful independent source of pressure which operates a piston instead of a diaphragm. These controls are "dead" accurate and expensive, but it is not within the scope of this article to discuss them.

*Editor's Note—This is not the only cause of hunting. Even the simplest direct-connected regulators may hunt or "chatter." Pressure-wave resonance oscillations are found in practically all simple pressure-responsive devices and under certain conditions a simple regulator such as a safety valve may be likened to the reed of a clarinet or oboe.—MFB

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